Introduction to Mechanical Micro Machining

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Lecture - 22
Components of the machine tool

Good morning everybody and welcome again to our course on introduction to mechanical micro machining. Today we are going to start a new topic and that is related to machining tool components. So, before we go into detail of this course, particular topic let me tell you what things we are going to cover in these case, because we know that machine tool is very important component when you operate or when you do some type of machining on a different type of work piece, end tool is also one of the parts out of the different components of the machining process.

But machine tool has one particular importance that what accuracy you are getting on to the work piece, mostly it is dictated by the construction of the machine tool, which type of material you are using on that, what are the different type of specification you are considering; that is most related to the precision of the different axis. Everything will play important role in making a component as per our designer requirement. So, we will go through the different components of the machine tool. So, that we can understand the role of each and every component and how they are important in getting the required geometry of the different work piece.

So, we will go through the construction of the machine, then spindle, then different type of axis, what types of bearings we are using, why we are using those types of bearing and what are the errors, because that is important, because when you making a or constructing a big machine, at that time you have to look into the flatness, perpendicularity, parallelism. So, those things will play important when you talking about micro machining.

So, let us go through this a particular topic and let us understand that how different components are importance for making a good components. So, those things are there. So, different between the machines.

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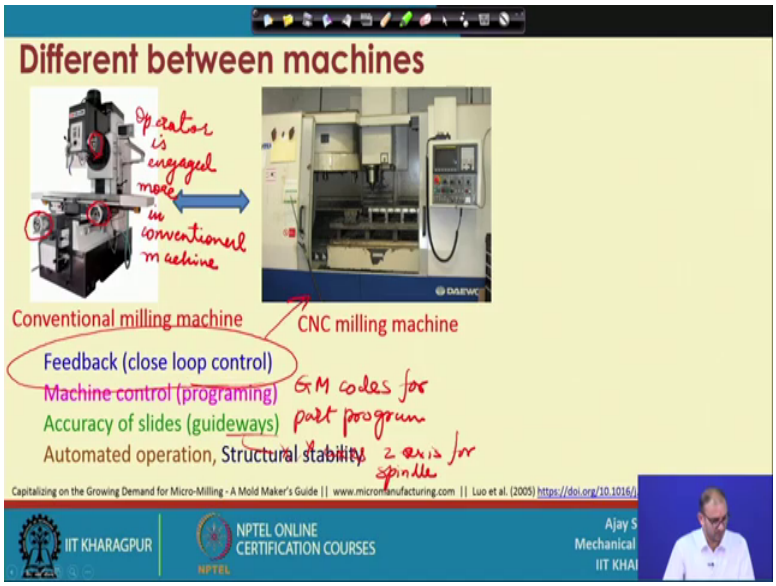

So, first let us go through the thing that how the machines are involved from a conventional machine to the very high precision machine. So, if you see this first machine; that is the conventional milling machine we all know and this is the CNC milling machine, and many time we can call it a as a machining centre also. So, how these two machines are different from each other.

So, here if you see these things; one is the feedback and close loop control. So, here in the conventional machine, mostly what we do that operator has a more roll on this particular machine. So, operator is engage more in conventional machine correct, why it is so, because in conventional machine operator has to do all the set ups and everything, and during machining also he has to operate all the things. There are automated feed is available, but mostly many times operator himself will do all this operations that moving the jog down and then do a small cuttings and many times it has to be perform in this case

So, engagement of the operator is more in the conventional machine, while here it is mostly on the part program. So, the operator has to write a part program depending on what type of work piece he wants to make, and then the machine will take that program in controller and then control will perform all the movement of xy and z axis. Another thing is that it if this one thing is the close look control; that is CNC machine because we have feedback device is installed in that, some machines also come without any type of

feedback controls; that means, you do you not use any type of encoders. Then machine control that is a programming, because in the conventional machining we will do not do any type of programming; that means, movement access is purely depend on the operator or machine pacificator the way you are engaged automatic feed and the automatic movement, but that is not that much precious compared to the CNC machine, because we do not do any program, because when you are operating a CNC milling machine we go through the GNM code. So, mostly it is known as GNM codes for the part programs correct.

So, that is the one of the differences is, and then other than that accuracy of slides and guide way that is also important, because when you are working with these machine, conventional machine you are getting little bit higher side of accuracy in the guides way and slide; that means, what we are moving in different axis. So, this are the things, so x and y axis and vertically also we are moving the spindle, that is the z axis, z axis for spindle right.

So, what is the straightness what are the perpendicularity between these x and y axis, everything dictates the precision of the machine automated operation, structural stability. So, those things are different in between the conventional milling machine and the CNC milling machine. Operator is automated in the CNC machine, automated in the sense that once you feed the program inside this controller, then controller will execute the program line by line and depending on the movement of x axis in xyz direction you can get your part machine very easily.

So, the automated operation in the sense of the operator engagement during the machining operation which is very less here. Only role of the operator is to look into this screen and understood that everything is going fine during the machining operation right

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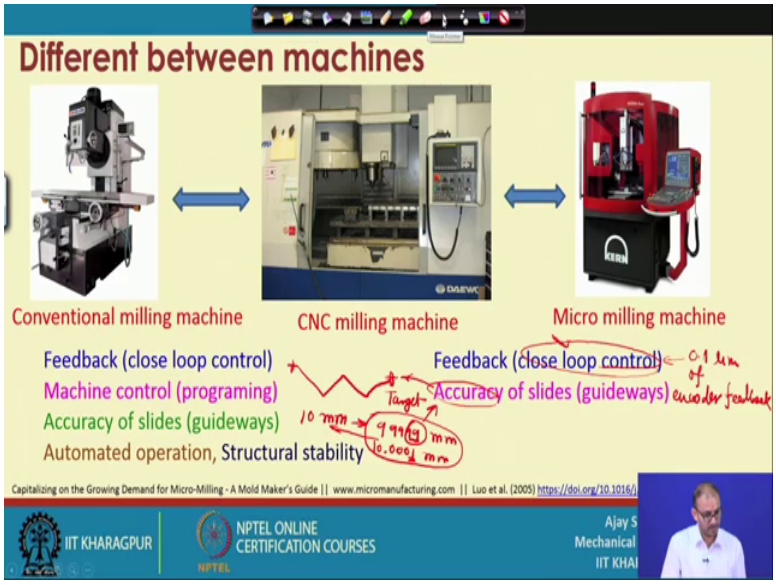

Now we understood the difference between the conventional milling machine and the CNC milling machine, but again there are some limitation of the CNC machine when you are working at a micro level, because there are many components which may not give a satisfactory results when you are working at a micron level, when you are working the tens of microns or hundreds of microns, sometimes this is also not enough.

So, we have another category of the machine that is called the micro milling machine. We will have one demonstration class on this (Refer Time: 07:12) machine which is we have in our lab. So, we can understand the different components, and a how this machine micro milling machine is different than the conventional CNC milling machine or the normal machine which also available in the lathe.

So, now let us see the how these things are different. Now again the same things feedback and the close loop control, but that is different here; that means, when you talking about hundreds of microns; that means, this close loop control has a encoder feedback of a 0.1 microns or encoder feedback, but that is not the case here. Many times in terms of 1 microns or the 5 microns of the encoded.

Sometimes encoders are not available at all, we have some machines were the feedback controller is not available; that means, movement feedback is not available. Accuracy of the slides and guide ways; that is when you are moving in a x and y direction what particularly you are moving in; that means, suppose you want to move from one, this is your starting position and you want to move to these position that is your target correct.

So, from here to here when you are reaching, how close you are reaching here that is given by the accuracy. So, suppose you want to move to the 10 mm, then you are moving to 9999 or 10.0001 mm.

So, how close you are reaching to the 10 millimeter that is dictated by the accuracy of the slide ways. So, those things are different, because we know that after each and every digit your cost is going to very high. So, up to which particular digit you want to stop; that is dictated by the how much money you want to spend on the accuracy and the feedback controller of the machine structural stability is more important here, because even a few microns of vibration here and there will destroy your all components.

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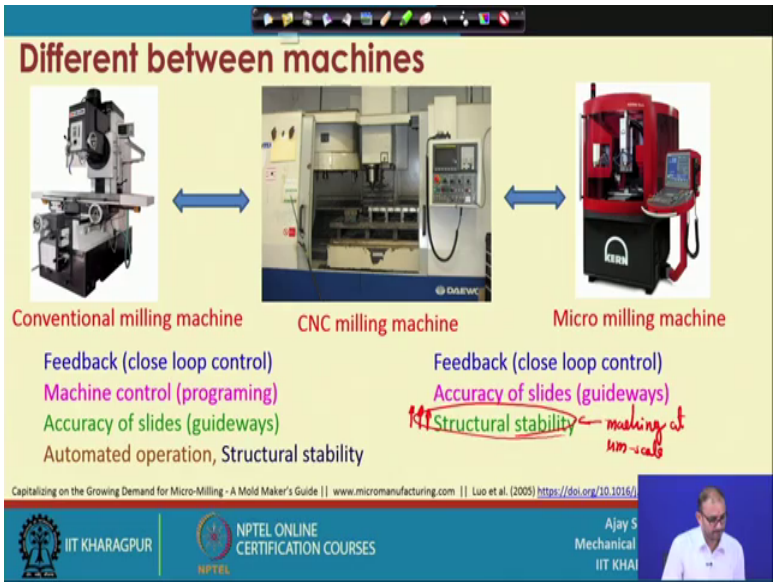

So, rigidity of or the structural loop stability should be extremely high in this particular case, and which is not the case of the first two. So, these should be very high and then only you can get the machining at micro scale.

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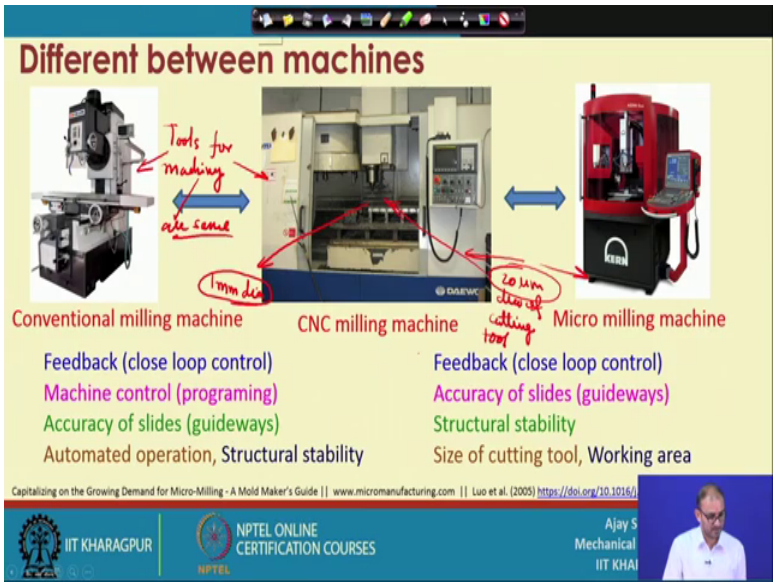

So, machining at micro scale correct size of the cutting tool and the working area, because now we know that what can we use the tool here, at these machine tool for machining, for these machines and these machines are same right. Mostly you can go up to 1 millimeter here also; 1 mm diameter and that again depend on the run out of the spindle and the rpm of the spindle, but less than 1 millimeter or 0.5 millimeter it is creating problem here, and here again it will be very high, but between these two, the difference is very large, because here it is reported that machining is done with up to 20 microns of diameter of cutting tool; that is very difficult here.

Because getting a 20 microns tool itself is very difficult and when you are putting 20 micron tool in a conventional spindle, you have to extract some of the very important pacificals from the spindle; that is basically a run out of the spindle, dynamic and static run out. We will discuss this parameter in much detail, but right now. Run out means what the obliging of the tool with respect to the axis of the spindle.

So, that is very important, because if it is more than 20 microns than; obviously, you cannot get any type of machining out of that part, because we are using a very small cutting tool here. So, basically that whatever is the run out, whatever the diameter of the tool you are using, your machine should expect that 10 percent of that particular would be the run out of that. So, if you are using a 20 micron tool then you expect that it should run out should be less than 0.2 microns; that is what is expected from the machine

Working area is again very less, because; obviously, we are not going to do machining on the large scale, mostly into 100 by 100 micron millimeter is enough for doing most of the work in these case, but in these two machine; that is CNC milling machining and the conventional milling machine, where you have very large amount of large size of the component and you can easily get machining done with a required geometrical specifications.

But here our specification and size and the dimension of the components are very small, and we have to create a very tight things between the all the structural stability and the accuracy of the slides and the feedback controller. So, this are the differences between the three different categories of the same machine, but if you see the size of the machines are almost same.

There is no much differences in the total volume of the machine; that is in the area multiply by the height of the machine, but the systems which we installed or which is available in different machines are different with respect to the components which you are going to cut through these machines. And you can see the this is size of the cutting tool and this is the point of a ball point tool and this is the cutting tool end mill cutter, and you can understand that how much precision is required to fabricate this tool and this is first tool that is the first thing, and where you are mounting of the spindle also play important role, when you want to extract the reasonable amount of work out of these particular tool.

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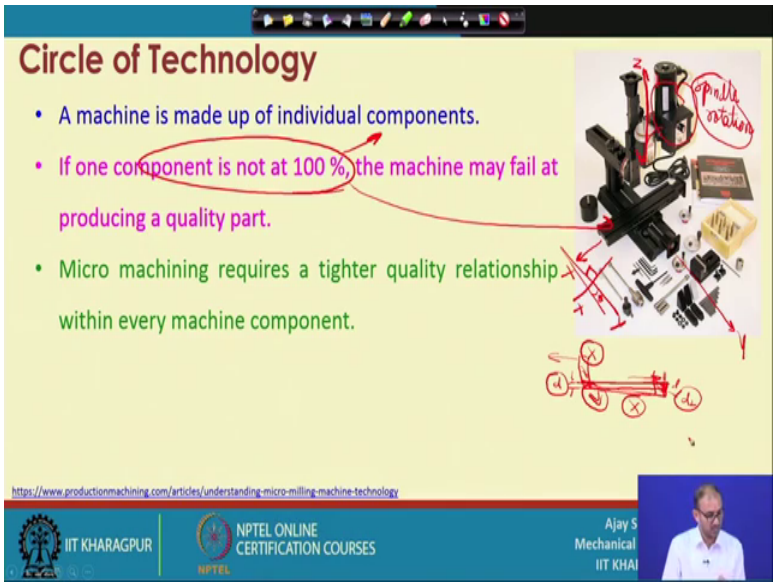

Now, what is the circle of technology that machine is made up of individual components. Now if you know that machine is consisted of many type of different components, it start, and contacting point is the work piece and the tool contentment that is called interference point, but if you continue; that means, the work piece is connected with a work piece holding device; that is fixture, fixture is connected with a x and y table, and then if you continue this direction you are getting a different components here. Now if you see this particular things.

So, this one is the x axis and this particular thing is the y axis and this one is the z axis spindle. And these are all three all in a linear movement, and once you get a this particular spindle here then you will get a spindle rotation correct, then for moving of these things then you have to assemble all the components and then only you can operate the machine. So, it has a many different components, and that will create a problem in getting the required results, because these are all the joint parts. So, if one components is not at 100 percent, the machine may fail at producing a quality part.

Now, you consider that everything is working fine, but your z axis of the spindle is not up to the mark. So, whatever you have some beakless here; that means, suppose you want to move 10 millimeter down, it is moving 9.54 or 10.5 or something like that then it is creating problem. If everything is fine, but you are not rotating a spindle up to a required rpm, then it is creating a problem. If z axis is working fine, but you have

problem or issue with a perpendicular with a x and y axis, then it is a problem, you want to do a straight cutting, but you are getting a incline cutting. So, to get a part completely 100 percent, you need a 100 percent output from all this components. So, that is why the circle of technology is important, that mean each every part should behave or should give 100 percent of their, whatever the required operation, then only you can get the things done. So, micro machining requires a tight quality relation within every machine components; that is what we have seen here that even a few microns of movements or the disturbance between the different things that is enough to destroy or reject the components which you wanted to intent from this micro machining center

So, that is why you have to be very care full in getting these things done; that means, the perpendicularity should be maintained. If perpendicularity is maintained, but then the flatness is not there, then there are problems, because you want to cut something like this straight line in this case, and because of this x and y is not exactly parallel and it has some angle theta, then your tool has right now here, and you want to cut from these to this much distance only and this is the depth is same from here to here. So, this is d and this is also d and, but because of this angle what you are doing you are cutting something like this. So, these will be d 2; that is not exactly d.

So, there are problems with many things here, because one that part is not as per the dimension, so part will be rejected. Another thing is your speed feed and depth of cut is decided, because of the depth setting, how much the depth setting you are putting at depending on the speed of decided, but now your depth is variable, once it reaches here your tool is going inside up to these much, but your parameter setting is calculated based on this much depth only. So, your tool may bend also, it may break also. So, you are end up with the breakage of the tool also and the rejection of the work piece also.

So, each and every small things you have to be very careful in designing the component, and again you have to also see, that after 6 month or after 1 year your machine is exactly giving the same thing whatever you are doing. So, that is called calibration of the machine, that is very important in micro machining domain right.

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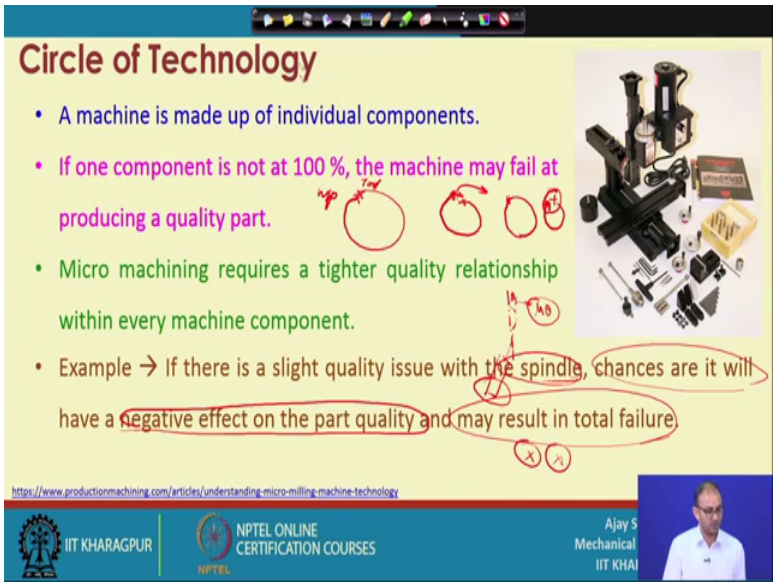

So, now, this is the example that we have discussed here, that if there is a slight quality issue with a spindle quality issue in the sense that it is either not rotating exactly as per the rpm, or it not aligned actually exactly at the centre. So, this is you consider the speed center in the z axis and this is you consider as the axis of your spindle, and then this is the angle theta; that means, your angle not matching exactly this part.

So, whatever tool you are putting here, let it be a few degree, a few micron degree only, micron degree or micron radios; that is also enough to bend your tool or not getting a required result out of that and ultimately your tool will be broken. So, those are the quality issue and the chances are, it will have the negative effect on the part. Some time you get the machining done, but you it is not exactly as per the specification and sometime it is a total failure. So, either work piece is not acceptable or and the tool is also broken before you do further operation on the component.

So, circle of technology is; that means, you need a full circle here. So, this is your tool and this is your work piece. So, both things should match. So, if any of this component is not here. So, your tool is here and then you will reach the work piece here. So, whatever is this distance that will be decided by these, the contribution of all the different parameters. So, we need a starting point and end point should meet, it is not like that we are reaching starting from here and we are ending from different location. So, how close you are reaching from starting to end point; that is decided by the different component,

the role of different component during machining operations. Characteristics of a machine tool.

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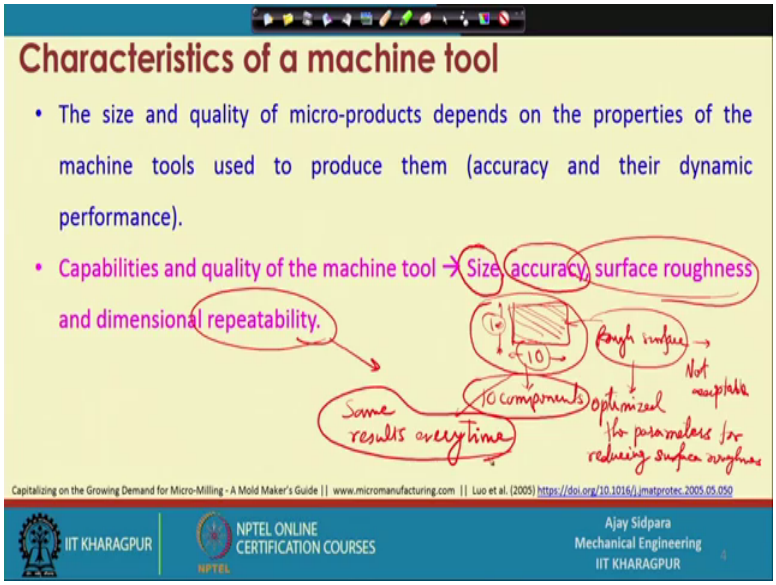

. So, now, the size and quality of the micro products depends on the properties of the machine tools used to produce them; that is that mostly the accuracy and the dynamic performance. Dynamic performance means, when it is in static we are not utilizing the machine, but the static deformation is also important, but that will take some time, but when machine in operation at that time the different components are in motion; that is the motion in xyz slide rpm spindle is also rotating. So, many movable components, at that time how the machine behaves that is also important, because that is the real life situation of the components.

So, capability and quality of the machine tool, is related to the size, accuracy, surface, roughness and dimensional repeatability. Size of the component; that means, up to what size you can cut the component and how precise you are cutting. Accuracy means if you are getting 10 by 10 size of the component and whether you are getting exact 10 by 10 or you are getting something different. So, that is detected by the accuracy. Surface roughness is important, because if your dimension is exactly what ever is the requirement or within the acceptable limit or tolerance limit, still you are getting a rough surface right. If surface is rough, rough surface is not acceptable. So, to get this things down what you have to do, you have to optimize the parameter for reducing surface

roughness correct. So, there are many issues. Dimensional repeatability is also there. Suppose in you in one component you are getting these dimensions, you want to continue with a 10 same type of components.

So, whether you are getting the 10 components suppose you want to make 10 components similar dimension. Then are you getting the same dimension or same result every time that is given by the repeatability. The same results every time correct. So, everything is dictated by the different component responsibility during machine operation.

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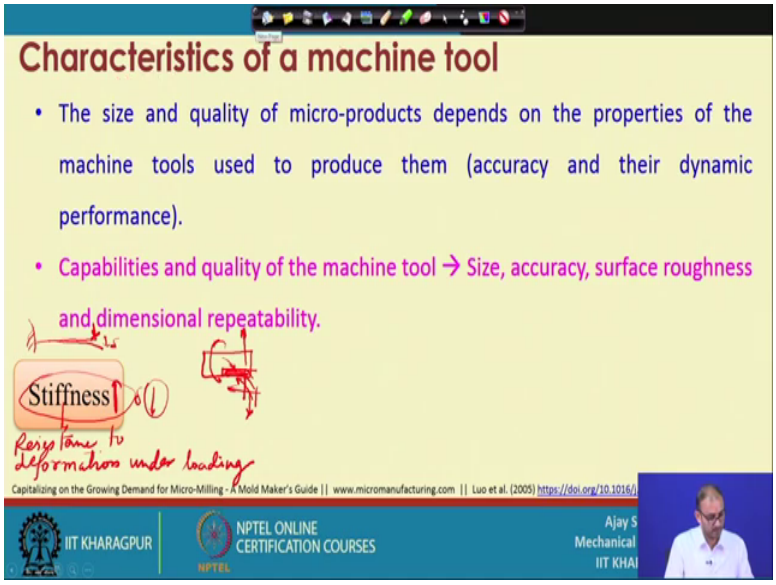

So, what things are important? First thing are important is the stiffness. Stiffness means resistance to deformation under loading. When your load, this is suppose continuity being and you are loading at the free end, how much it will deflect that is depended by the stiffness. So, higher the stiffness, lower will be the deflection. So, this will be, so it will go little down very less down if the stiffness is high; that means, flexible, it is opposite to flexible. Flexible means if you are giving a small force your things will bend very quickly or without any type of persistency. So, that is why stiffness is more important, because we have physical contact with a tool and work piece right. So, our work piece is here and we have tool which is moving in this direction with a depth of cut inside. So, basically you want to remove the material from this parts.

So, this much amount of physical persistency is also provided from the work piece and tool is also providing the enough amount of forces. So, under these particular condition how much is the stiffness. Suppose you want to move from here to here, weather you are exactly cutting in the same direction or your work piece is bend in this direction and sometimes tool is also coming out of this direction.

So, that is decided by the stiffness of the different components of the machine tool.

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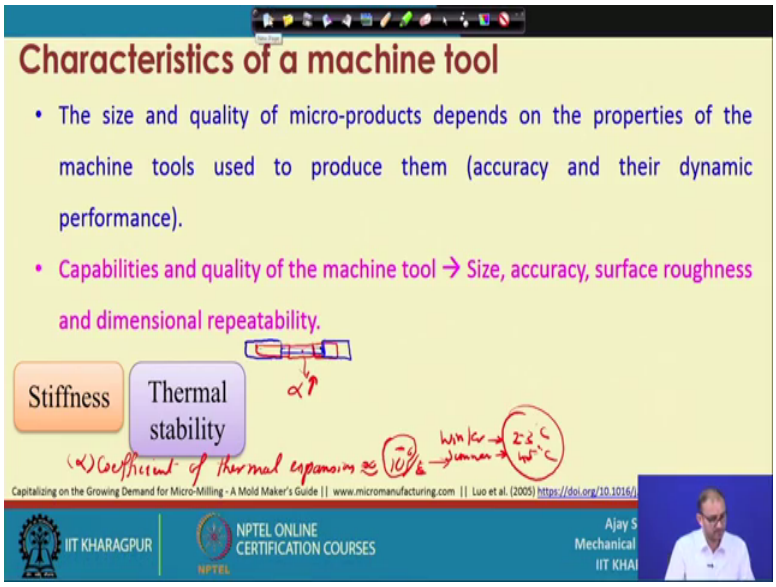

Another thing is that thermal stability because temperature has a very important role in the micro machining specially, even a small degree change here and there will create a problem, because we know one parameter that is called coefficient of thermal expansion, and it is mostly given in terms of 10 raise to minus 6 by degree centigrade in most of the metal; that means, with a 1 degree centigrade change in the temperature, how much is the expansion or the construction of the component. Mostly it is in micron, if it is in micron you can understand that we are also working in the micron domain.

So, small change here and there. Suppose we are putting our machine in a open environment and we know that we have a temperature distribution in the different season. In the winter sometimes it is reaching 1 to 2 degree, 2 to 3 degree. In summer it is reaching to 45 degree also. So, such a large difference in the temperature also play important role. So, this is very large, but we are talking here degree change in the 1 or 2 degree.

So, even if you keep inside a envelope, still you have to maintain the temperature, because each and every components are physically clump together. So, suppose this is the one component, this is the second component and third component, something like that, and this one is considered alpha, this one is a high alpha; that means, components of a thermal expansion is very high in this case.

So, these particular thing will expand correct. So, this will expand. So, diameter is decreased and the length is increased. If this expansion is this, this is the highly exaggerated, but you will at least get in few microns. If this is happening then what will happen, this particular components will move in this directions, this will move in this directions. Since everything is closely paired, even a slight movement here and there will disturb all the assembly and you will end up with the some permanent deformation into the machine tool.

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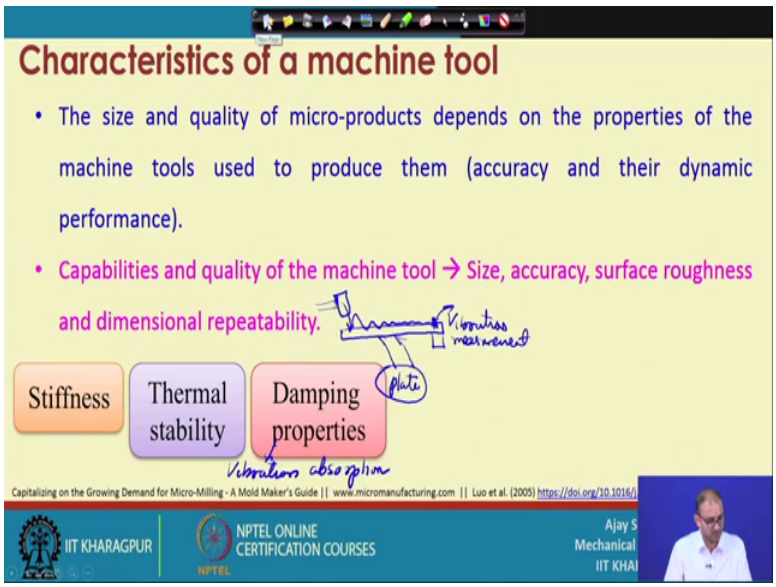

Damping properties; Damping property means the capacity of vibration absorption; that means, suppose you have one table here let us consider, and here you have sensor and you are hitting with a hammer at this location, you are hitting at this location.

So, when you are hitting here, and you are measuring the vibration at this location. So, when you are hitting here vibration will propagate here and it will reach to this particular location. So, whatever is the property of this particular table or this is the particular plate, that will dictate that how much vibration will propagate up to this particular point

correct. So, if you are hitting very hard and these particular thing has a very low damping efficient, and then there is a problem of propagation.

So, all the vibration in propagate it will reach to this location and it will continue for a little bit longer time also. So, what we need we need a damping property should be very high in this case. So, that all the vibration will be absorbs within the material only, and it will not reach to the another joint here. If it is to that joint after sometime joint will be little bit loose and then it creates a problem in the other assembly part. Accuracy is important that we have seen in the last previous 2 3 slides.

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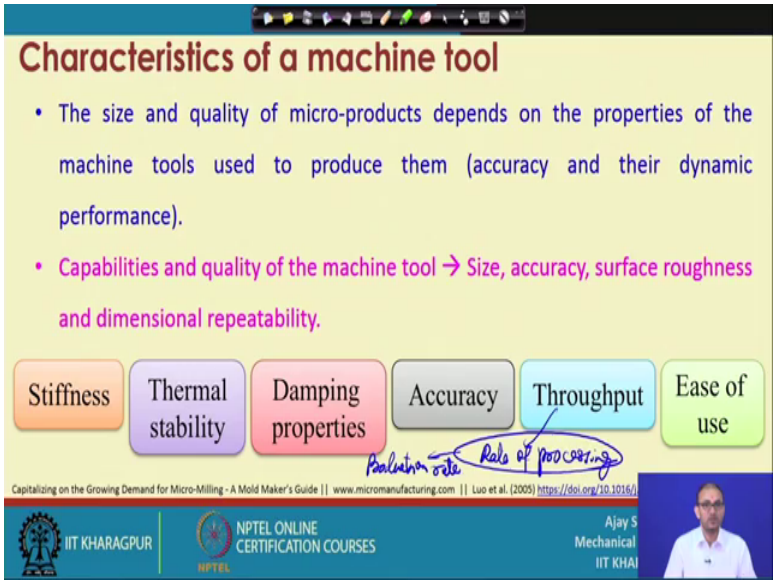

Throughput is also important that how many components you are getting that is called the production rate, rate of processing or we can say it the production rate correct. So, that is important, because even if everything is there, we should have reasonable amount of throughputs. So, that we can just justify the cost verses the production rate, because the cost of the machine is; obviously, very high.

But if you are not able to extract the required amount of work out of it, your machine will not be useful for other different operations, and ease of use is important, because we know that operation and the things which you have to take care during operating a micro machining is different than the conventional machining, in the last few lectures we have seen those thing, but still it should be very easy, because a person should be a very, he

should feel very comfortable learning the machine also, and it should have, it should not have so much of sensory things and understanding the things about the process.

So, let me stop from this particular slide. And we will continue this topic in the next class comparing with the other systems and the parts.

Thank you very much.