Introduction to Mechanical Micro Machining
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Lecture – 26
Components of the machine tool (Contd.)

Welcome everybody to our course, on introduction to mechanical micro machining. In the last class, we started with a discussion of a three parameter or the three different characteristics that is accuracy repeatability, and the resolution, and we have seen that if the resolution of one of the components is less than your whole system cannot be operated to the fullest and for which it is specified. So, that was a problem and again it will create a problem with the accuracy. So, now let us see further, in this case that what are the different type of configuration of the machines and which configuration is important for making a micromachining machine.

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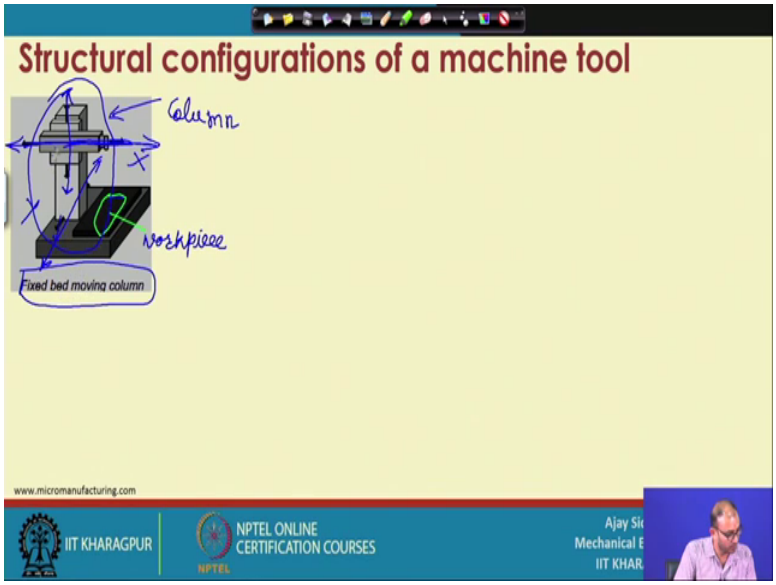

What are the difference structural configurations? Mostly here, what we are discussing, we are looking at the three axis machine only. So, we can see that what are the different ways, we can identify those axis so, this is one of the axis, where the tool is moving or the X is moving in this direction and this is one work piece that is equal Z axis and this particular X is called the X axis and this particular axis is called the Y axis and your work piece is located at this location. So, this is the location of the work piece.

So, now what are the movement here? Now, you can see that, only your table does not have any axis. Here, your whole thing is mounted on the column and this particular column has all the three movements, all column is moving in Y axis direction, then at some height you have mounted A X axis and then this Z axis is moving in this direction. So, this is called the fix bed moving column. So, your bed is fixed, but your column is moving in this direction.

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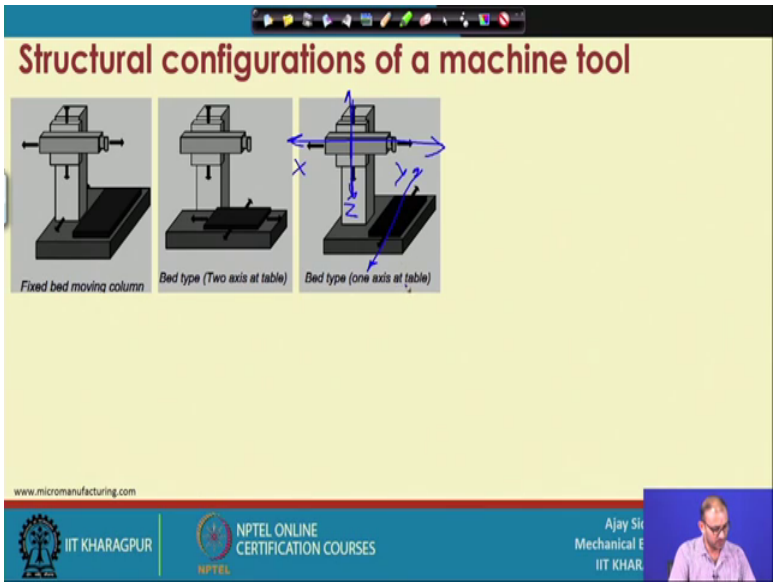

Second is the bed type here, what is given that two axis are in the table. Now, in this case if you can see, there is no axis on the table, but it is a bed type. So, only your Z axis which is moving in, that is the only moveable axis on the column, but remaining two axis are on the table right. So, that is called bed type construction and this is a third time here, again it is called bed type construction, because still we have one axis moving on to the table or the base, but two axis are mounted on to the column. So, this is the one axis that is Z and this is the X axis and your Y axis in the table. So, that is called one axis on the table.

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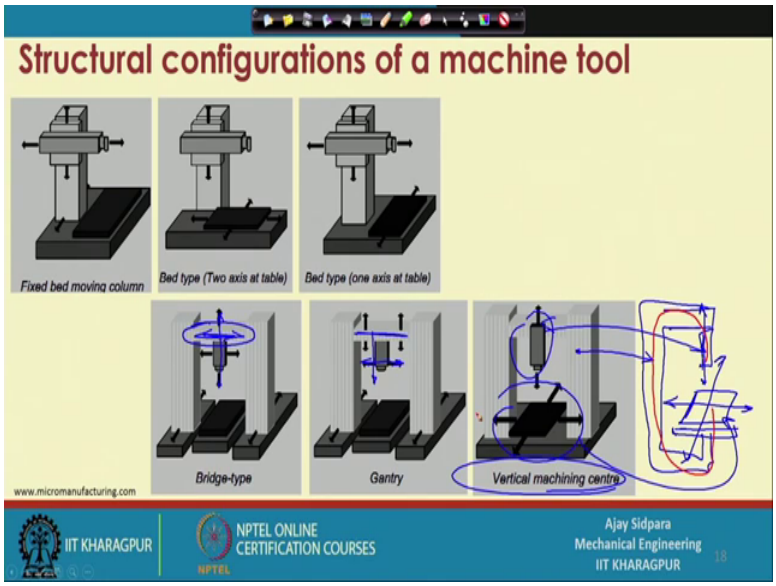

Now, this is called bridge type construction. Now, what is here that you are work piece or the table is fixed? Now, here at this location, but what happened that this whole thing is a bridge and this all bridge is moving in the Y direction and your tool which is actually on the centre of this bridge and then your Z axis is moving up and down in this direction as well as it is moving in the X direction in this direction.

So, here this work piece, you can also see that this particular thing is independent, then the movement of this Y axis. So, this construction is also very popular in machine tool and this one is the gantry type of things here, what is the thing that still there is no movement on to the work piece side, it is almost same here, that you can see that Y axis is same, is the bridge type thing, but what happens that you are in this particular location, your tool was your particular bridge was the fixed one.

That means, there was no movement on the bridge, but your tool was moving actually on this bridge. So, it is move, it was moving in the X direction on the bridge and then it was moving in the Z direction, but here what is happening that your tool is actually capable to move in the X direction only, but this whole bridge will move in the Z direction. So, this is another configuration of the machining structure and there is still no concern connection with all axis, with the work piece. And this is the last one here, it is called vertical machining centre or it is called the C type construction that I will show you in the next slide, that it is similar to this type of thing set, your table is located here and it is

moving in this direction and this direction your tool is located here, tool is moving in up and down motion and this whole thing is structured in this way.

So, this is the construction of this particular beds type and this tool is located here and your table is again located here. So, table or the work piece is moving in X and Y direction and your tool is moving only in this Z direction that is on the overhang portion. So, that is why it is called the vertical machining centre or this is called C axis, because here, the structured loop is something like this. So, this is called the C. So, that is why it is called as a C construction. So, now, question is that which particular configuration is good for higher stability, higher stiffness and whenever there are force is acting on the tool or the work piece is at that time, it should not deform permanently or the temporarily.

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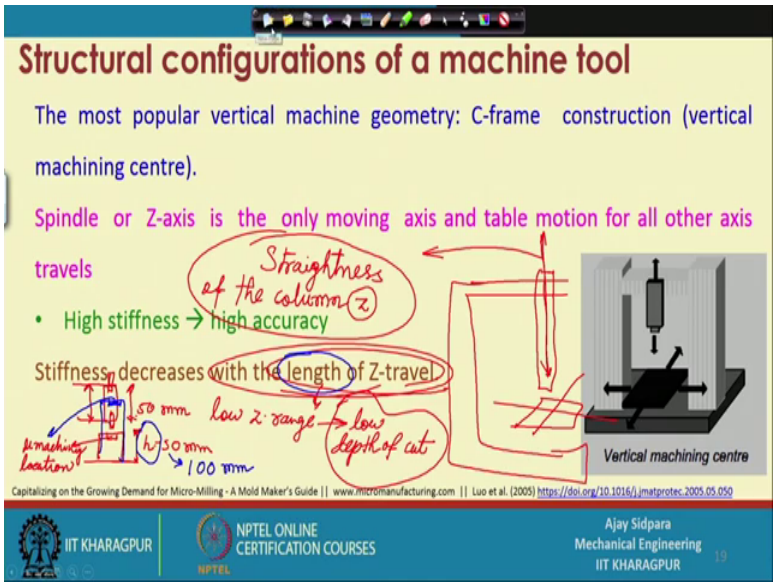

So, now let us see the out of the six configurations, which one is better. Now, which one is better, that this particular thing is the much better this called vertical machining centre or it is called the C axis type of thing, why it is? So, let us see. So, most popular construction is this C frame construction or the vertical machining centre. This is this one, why it is? So, that here what is the advantage here, that a spindle or the Z-axis. What it is showing, that it is only moving axis on to this particular part. So, now, if you see here, the spindle axis is only moving in other than this particular set of, if your seen that earlier slide, many motions were given here and here at this location, but that is not the

correct one. So, when rest of all the motion; that means, X and Y motion both things are located into the table.

So, why it is important here, because whatever structure your making like, we know that getting a perpendicularity between the two surface, it is extremely difficult, because even if there is a problem in the few microns here, and there that is enough to destroy the component or the operation at the later stage, when you are using that particular defective machine or micro machining operation; so better that whatever moving X C Z, it should have minimum amount of movement, in different direction. So, this is the configuration, where you have only spindle or Z axis, which is moving vertically in this particular case and that is a very big advantage compare to other setups.

So, what is advantage is the high stiffness and high accuracy, because if your stiffness is very high, we know that your machines tool structure will not deform and then rest of the things is depending on the encoder and the position movement, whatever we are using that we have seen in the resolution part that depends on them, that what your selecting for that, but because of this high resolution and high accuracy end up, with the high accuracy and this is the way, this structure is very important, but still there is a problem here also, because if you increase the length travel of the Z. Now, consider that suppose, your Z travel is this much and then this is the remaining parts and your table is located here, it is moving in this two direction, and this is the base of this machine.

So, more this thing; that means more you have to look after the straightness. So, straightness is important or it is an issue straightness of the column Z. So, this is creating a problem, because; that means, where it is creating problem that you cannot actually put a work piece very big here. So, that you want to do a drilling suppose, in a 50 millimetre or something at that time travel will not be that much. So, you have to work within a small movement of the Z axis; that means your depth of cut will be sacrificed in this particular case.

So, if you are working with a lower Z range low depth of cuts, because you are going inside the work piece and that is creating problem, but still we know that we are working, we have to do some machining or something and micro scale and few microns here, and there it is not a big issue here, but still you have to consider this part very comfortably, because many times what happened that suppose, your tool is located here,

and we know that it can move from here to here, consider 50 mm and this is the base of the table and this is the work piece, you are putting here. So, work piece has also one height. So, let us name it H and your tool is located here, which will do machining. So, now, what happens that, this is the total range of the travel Z travel? So, now, your tool is right. Now, here it can move up to this location up to 50 millimetre.

Now, consider this is the one location it is very easy that mounting of this work piece from this location is very easy, because H is suppose, consider, let us say that this is also 50 mm and you want to do small machining as you want to create some features here, micro machining location. Now, there is another problem. Now, let us see that now we have one more work piece, which has a height little bit high that is not a 50, but suppose, it is 100, now, H has a 100. So, now, we have to put 100 here. So, this is almost double than this. So, now, why this Z axis play important roles, because if you have variable height of the work piece and every time your objective is to do machining here only, same way whatever we are doing in the earlier work piece, but now height of the work piece is little bit large. So, to accommodate such type of work pieces, what we need we need adjustment or the long length of the Z travel.

So, that is the only reason, but our machining process or the machining depth will be; obviously, low, but when you are putting a big work piece or the long height, work piece at that time, it is an issue, but that is not a problem in every time, but sometimes you have to also think about that, what are components you are planning to machine; by this particular machine depending, you have to design the Z axis.

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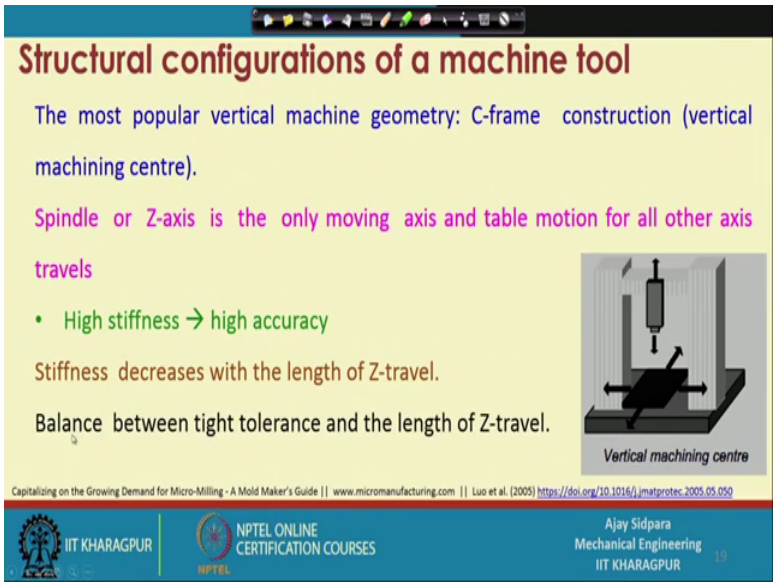

So, what we need? We need a balance between the tight tolerance and the length of the Z travel, because if you are moving of, you are making a very long Z travel then at that time, there is a high chance of creating a problem in terms of the run out, in the axis symmetry. So, we have to make sure that we are getting a tight tolerance also and there is a reasonable length of the Z travel available. So, that maximum number of work piece with a different height, you can machine without any problem.

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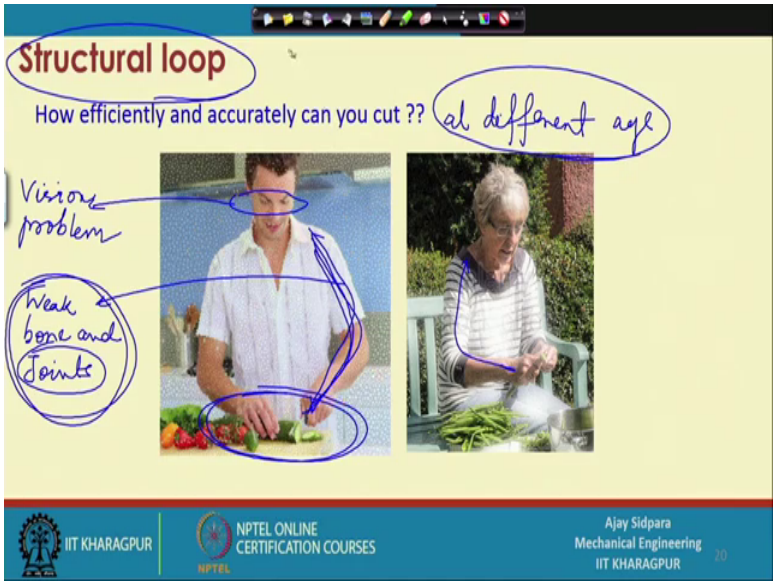

Now, coming to the structural loop; so, what is this structural loop that for understand that thing, let us take one example; will be the how efficiently and accurately you can cut? Now, there are two personal; one is a very young guy and there is one adult, who is both are cutting vegetables here. Now, what is the problem here, that suppose you can understand that if when we have become little bit more aged at the time, when there is a problem in our structure also, this become little weak bone and joints vision is also a problem. How efficiently you achieved cut? You can cut with, not with, but at different age.

So, now you can see that this person is standing, but still it is able to cut, but when we become little bit older, at that time what happened that our strength and everything it decreases and we are not able to cut as sufficiently as this one. So, there problem is the joints and everything. So, same thing is in the machine also, because when the machine is completely new, at that time all the axis and everything works very fine whereas, the time passes, there are problems in the joints, than your end up with some of the loose connection in between the joints, which are very difficult to identify unless, you do some type of calibration and there is an aging of the electronics components also available, because everything will not work as fine as at the starting and after 1 year or 2 year.

So, everything will create a problem in the structural loop, but right now, what we are pro making, why taking this example? What we are discussing? We are discussing about the joints and the bone strength. So, if your bone strength and the joint strength are very stiff or very high, you can actually do very easy cutting in this case. So, same thing is in the machine. So, let us see that how we can correlate this example with the machine.

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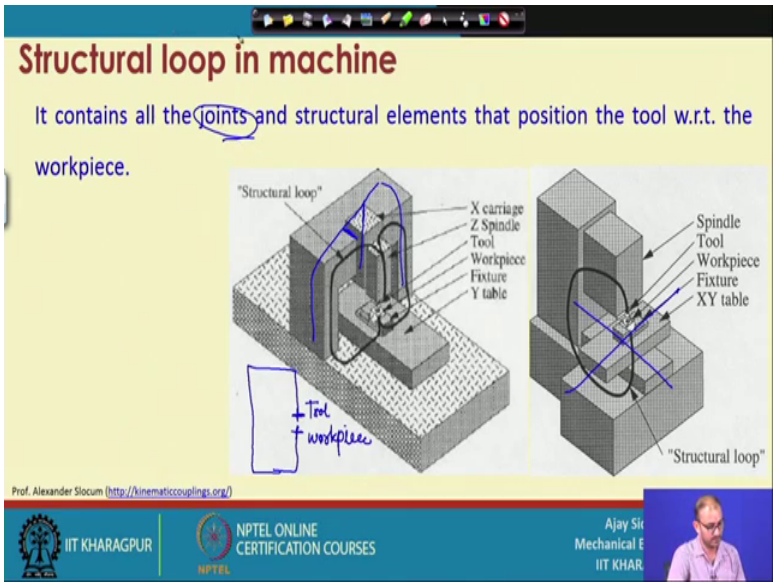

So, what is the structural loop in the joint, in the machine that it contains all the joints structural element that position, the tool with respect to the work piece. So, now, these are the two configurations that we have seen in earlier slide, that this particular thing was the vertical machining centre and we have also understood, what is the C construction. So, here this is the C construction, because this particular thing is considered as the C type of thing and here we have two loops, because this column is taking care of the balancing of the Z axis.

So, that is why it is called the structural loop, this thing. So, now where this structural loop starts, because this whole thing is connected only opening position or the vacant position is the location between the tool in the work piece, because we know that we have a tool and this tool is actually going from upward and then we have work piece and that is coming from the down correct.

So, now, when you are joining these two thing then our loop is completed, this all thing is fixed. There is no problem in that, but whenever you are joining this thing, joining means you are not joining just stationery, because they are in a dynamic position, there are material removal, lot of forces are acting between the tool and work piece, then all this particular thing should able to absorb the show and without any permanent, what the local deformation. So, our structural loop is contains all this joints and structural element, because this is called structural element and whatever is this thing that here, we

cannot. We know that this thing is moving up and downs. So, this is a joint and then we know the X travel and Y travels is also moving in this different directions that is also considered as a joint, it is not the fix one.

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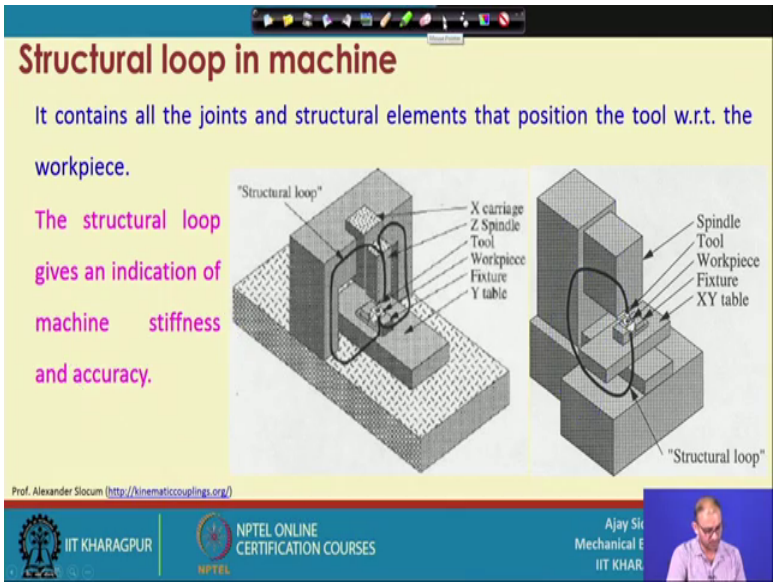

So, structural loop gives an indication of the machine stiffness and accuracy. Now, consider that if there are some problems in the joint. Suppose, this there are some bolt, because either it is a bolted or it is a fix by in terms of some type of slots. So, if there is some problem here what is happening that it is not exactly moving vertically, but it is moving little bit in this direction, or maybe in this direction, or may be in this direction this.

And; so, this we will see the what are the geometric errors, but now, if in this particular case, what happen that your stiffness is reduced, because whenever you are working with a loose connection and your giving lot of forces here, this particle loose connection, will again propagate the vibration throughout the system and; obviously, you are not able to get any machining operation with a high accuracy and that is the problem with this type of structures. So, these are the two structure let us discuss this two structure of first.

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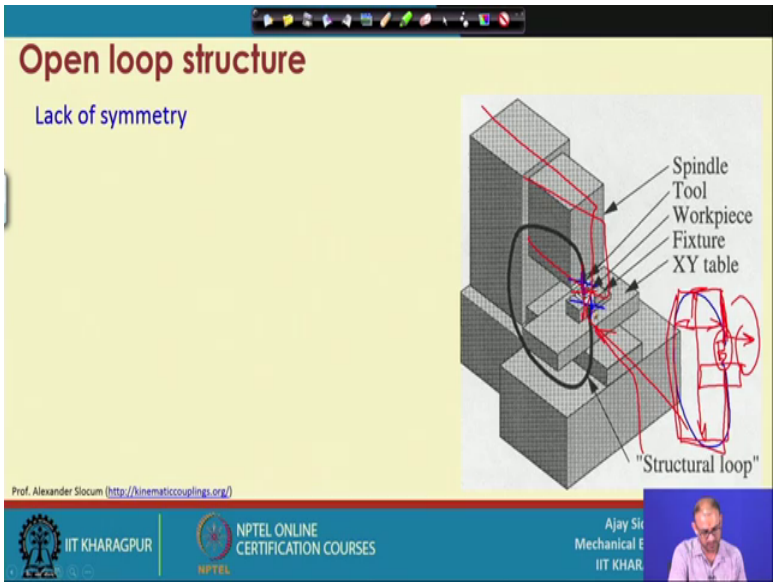

So, this is called open loop structure, because now, we have seen earlier two structures. So, this one is open loop, because this all structure here you are not able to mix or you are not able to fix two things together here. So, this is the location of the work piece and tool. So, this is called the open loop structure. So, what are the problems with the open loop structure? What are the good things, there is the lack of symmetry.

So, what happen here, we know this, these are the two things and whenever open loop structure; that means, this particular thing is at this direction. So, which way it is open that there is a distance between these two and there is a distance between that these two also, because our base is located here your tool is located, work piece located tool is located here, and how much is the distance overhanging part and what is this particular long length also vertical length.

So, that will be decided by that part and here problem with that, it is not symmetric structure; that means, that when you do machining at the time, this location is here, but from here at this particular location nothing is there, but all the thing is located on the one side that is on the right hand side. So, if you actually may consider this one as a centre, if you see from this direction, this is actually equally divided in this all part. So, considered this is the one part, but if you see from this particular direction, actually this whole thing is overhanging part right. So, overhanging part is very problematic, when you are doing working with a micro machining or the micron range dimension.

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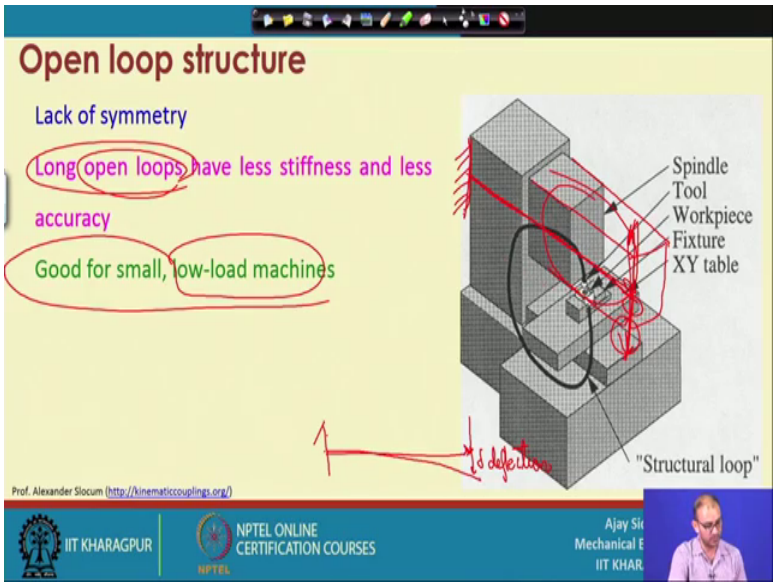

So, what is the problem? The long open loop have less stiffness and less accuracy, long open loop means that suppose, this particular thing is little bit extended, this is the thing now consider. So, this is more extended then your tool is located here. So, whenever you are putting a force here now, you know that it work as cantilevers beam, this one is a fix one. Now, consider, let us consider cantilever beam here itself. So, this is a cantilever beam and this is your fix point, this is your free end and your cutting tool is attach, this location. So, your forces will move in this direction, because you are pushing, the work piece also resisted particular cutting it, make direction then you are getting a force in this direction.

So, whenever your moving's be and it has this weight also it is own weight is all, because we have seen in the scaling low that your cantilever beam will deformed, because of it is own weight also and, because of that you are getting one deflection that is called delta. So, because of this what happened? These are called very long open loops, but if it is very small, I think it may not give any. So, much of a problem, but still some machines available, which has this type of C structure or the open loop structure, but wherever is small amount of open loop in this Z axis extension, of this Z axis bar or this particular column is not so high. So, that you can get this thing, where is the advantage that it is good for small and low load machine; that means, when you are machining with a very fine features and some more type of a low load machine.

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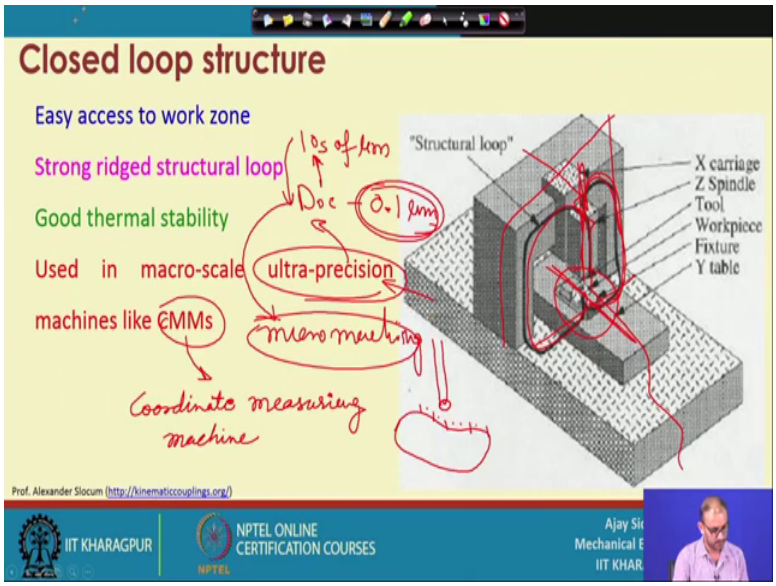

Then it is good and you can still use for the micromachining, then the closed loop structure, this is a closed loop structure. Now, what is the advantage here, because all the thing again, it is a symmetric on both the sides and your work piece is located at this particular location, but now, if you see here that these are the two loops, which is taking able to separate the all things from this particular side and then your Z is moving up and down from the direction and your work piece is moving in the X and Y direction here and now, considering the support of the Z axis, comparing the earlier slide.

You can see that this all structure is very stiff in this case and that is the reason, the stiffness of this particular closed loop structures are very high compared to the open loop structure, that easy access to the work zone, because now, here, see that you have large area here and you can easily access some most of the things here and the strong and ridged structural loop.

So, here we have this structural loop, it is very strong, because now, it is combined from the both, it is supporting from the both sides and this is actually at the centre. So, it should not create any problem and very good thermal stability, because now, we know that each and every material has some thermal expansion coefficient. So, if there is a large variation in the temperature what happen this, because the symmetric structure, whatever then your tool will not deviate from the centre of the access that we have seen in the last, probably in the previous two three lecture that how the deviation of the tool

can be affected by the variation in the temperature. So, symmetric structural are very important for this type of micro machining operation and mostly it is used in the micro macro scale ultra-precision machine and like C M M. C M M is the coordinate measuring machine, because many times, what happened that C M M is coordinate measuring machine.

Now, what this machine does that you put a work piece here and there is a prop and this particular prop? Now, suppose, this is the work piece and this is the prop. So, what this prop does? That prop will touch the surface in every time, it will find out what is the coordinate of that particular location. So, if you do not have a cake drawing of the 3D model of any component and if you want to generate a 3D component or the 3D drawing out of it then this prop or this C M M is very useful, that it will get all the information data cloud and after data cloud or you can do that you actually join those, your points in terms of different curve fitting techniques in you can get the real picture of that thing and after that you can convert into the different type of drawing or the different type of use.

So, that is why it is useful when this is ultra-precision machining, because in ultra-precision machining. We have seen that different examples that we are working with a very small amount of depth of cut, because in ultra-precision and depth of cut is starting, you can go with the point, one micron also, but in micromachining what we do that, we actually go with the little bit small, little bit higher, it is in the tens of micron. So, this is what is difference here. So, when you are working with a very small depth of cut of the small feature machining, at that time more stability is required. So, ultra precision machines are also very stiff in terms of the moment or in terms of the machine characteristics. So, that is very important. So, what are the parameters which affect the structural loop?

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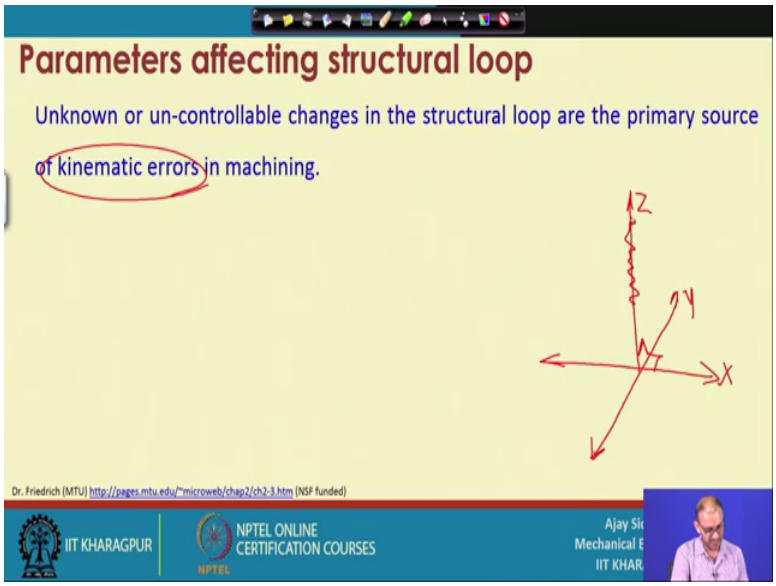

So, there are many things is unknown or un-controllable changes in the structural loop are the primary source of the kinematic errors in the machining. So, what is the kinematic error; that means, kinematic error means, we have three axis; X Y and the Z one and all this axis are perpendicular to each other. These axis are this one, this one is this one and so, this is the Y, this is the X and this is the Z 1.

So, kinematic error means if any of the axis are not exactly perpendicular to each other, then it will create a problem in the machining, if it is not straight then it is a problem. Suppose, it has some angle between these two, then it is a problem. Suppose, if it is a straight, but it has some problem in the construction of; that means, your whole thing is not exactly straight one, but it is a perpendicular between the X and Y, but if construction is not good, then it is also kinematics error. So, we will see this thing in detail.

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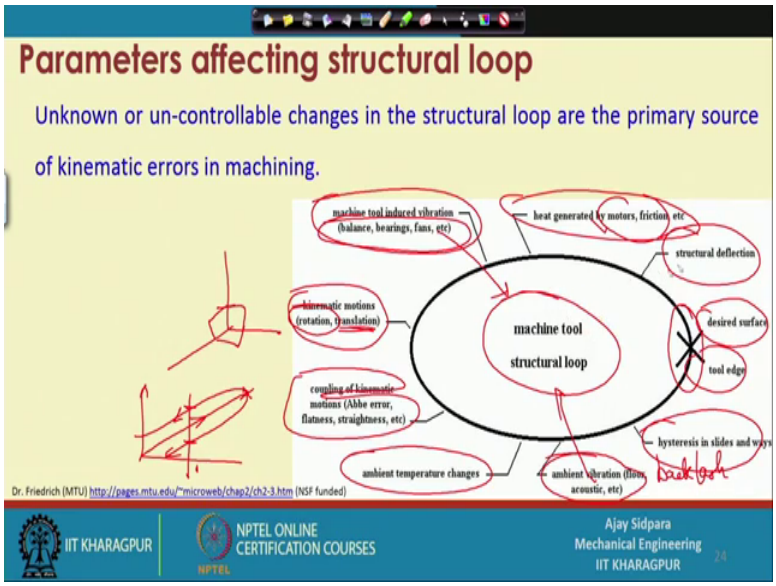

So, this is called the structural loop. So, machine structural loop is at the centre and what are the things it will affect? There is a machine tool induced vibration, because we know that we have machining operation, going one lot of force is acting and we are moving at tool or the work piece in different direction to and fro in X direction, Y direction, Z direction, and everything is connected with the bearings, because you are spindle is lot of bearing things are available.

So, it will create lot of vibrations there and, because of the vibration what happen that, it will directly affect your structural loop heat generated by the motor and friction, because if it is generated, we know the coefficient of thermal expansion, material will expand even if there is a change in the 1 degree or 2 degree at a micron level and that is in a structural deflection, is there, because if there are a lot of overhang portion available and, because of the overhang portion, you are end up with the loosening of the structural loop and this is the desired surface, this is tool edge on the other side hysteresis of the slides and the ways that hysteresis; that means, your backlash; that means, when you are starting a position.

This is considered one location, you are starting in movement at this location, but you are not going in the same direction, at the time, it may go, return path is different and going path is different. So, in that case you have a two output at one particular single input. So, that is creating problem. So, hysteresis in that particular ambient vibration floor acoustic,

they for that, we have seen that another machine is installed, site by which is beam vibration mode that vibration is propagate inside this machine structure and then it will create a problem temperature change, ambient temperature; that means, even if you control this friction heat motor vibration.

Heat generated here, but if you are ambient temperature change; that means, variation within that climate, where the machine is installed then again the structural loop will be affected coupling kinematics motion abbe error flatness straightness error; that means, this is what we are talking that axis should be perpendicular to each other and if that is not the case then you are end up with the some type of structural loop deformation kinematic motion, because we know that we have translation also X Y Z direction and rotation around the Z direction, that is in three axis machine, but if you rotate in other two axis, you can again get the more thing.

So, this all different parameters will affect, where it affecting point is the contact point between the surface and the tool. So, at that time there are problems associated with this. So, we have to take care about all this things and then only we will make a structure, which is a high stiffness and, if change tend to maximize the error between the work piece and the tool.

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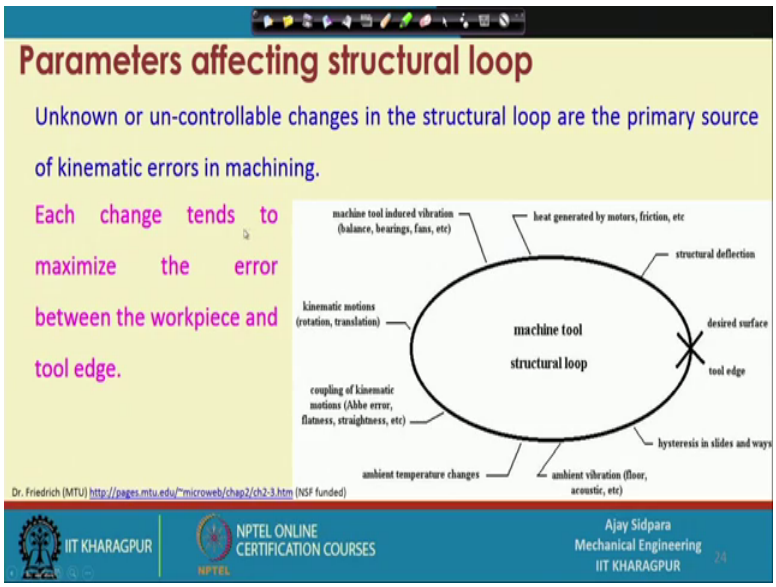

So, if not that which parameter is more important, we have, but all parameters are important. When you are talking about a micro scale machining, you cannot avoid

anything here and that is the way that you have to build a machine in such a way that there should not be any type of problem from the any component, otherwise rest of the compound will be also affected by any problem.

So, let me finish this lecture here and we will continue this topic further in the next class.

Thank you very much.