Introduction to Mechanical Micro Machining
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Lecture- 31
Components of machine tool (Contd)

Good morning everybody and welcome again to our course on introduction to mechanical micro machining. In the last class, we have seen some of the geometric errors and how those errors will affect the performance or the quality of the component, which we are making by micro machining operations and we have seen different- different errors in X direction, Y direction and Z direction and we have seen a simulation or one animation, where it is showing that different - different type of errors in different direction according to the coordinate system.

So, let us continue this topic further.

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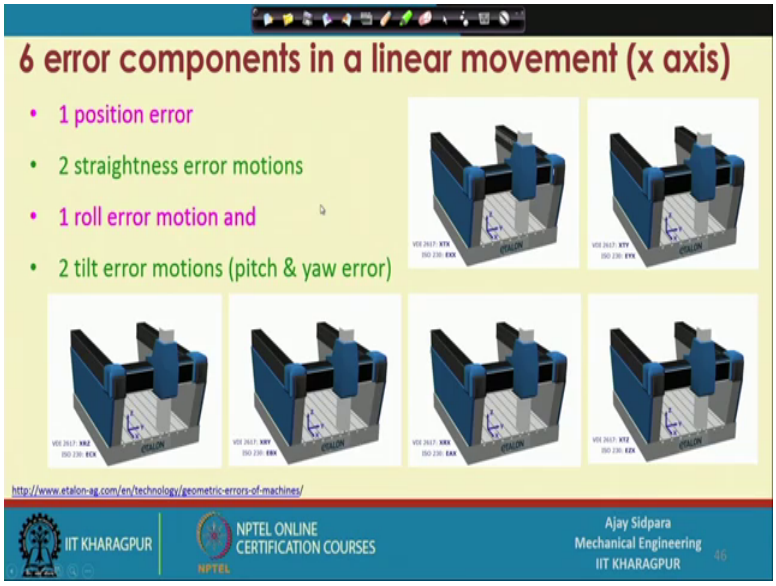

So, we have seen in the last class about the X axis error components, when it is moving in the linear direction, there is a X axis and we have found there, 1 is the position error, 2 was the straightness error, 1 was the roll error and 2 are the tilt error and similar to that, we have seen when you have attached one rotational axis around the Z axis, then you can end up with some more errors in the same rotational motion.

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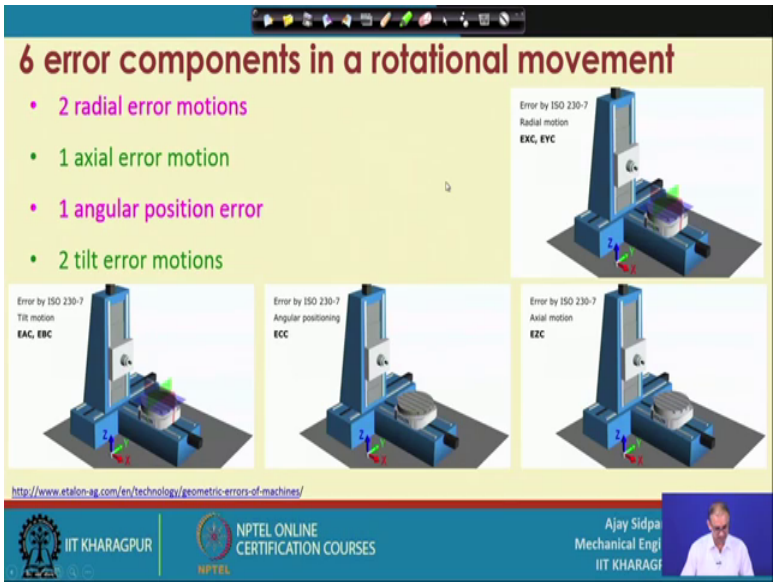

So, that are the 2 radial error. 1 axial error, 1 angular position error and the 2 tilt errors.

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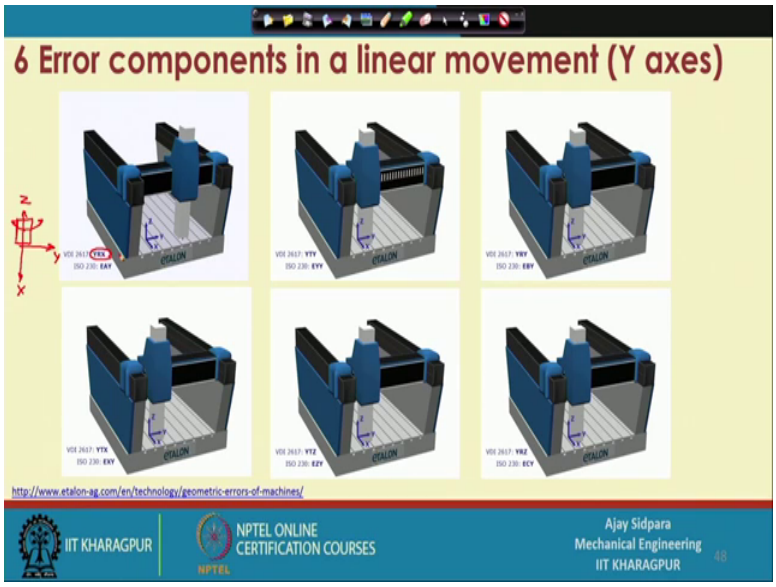

So now, let see same thing for the Y axis, then how the error components are in different - different direction in the Y axis. So, first one is this one. Now, you can see that it is moving, but it is tilting around the Z axis, that is in X axis. So now, if you see this thing, so, this is the coordinate system. So, this one is the Y axis, this one is the X axis and perpendicular to both - that is in vertical, this one is the Z axis and your spindle is in this direction, correct?

So now, when it is moving, so, it is actually swinging in this direction, correct? So, that swinging direction actually is the X direction where it is taking the center of that X axis and it is moving. So, that is why it written there error in Y axis, but rotation around the X axis. So, Y, R, X. Now, coming to the next one; so, here it is in tilt motion in the Y direction. So now, it is translation motion, not sorry, it is tilt motion. Now, you can see again, these white color and the red color; what we need that for uniform motion.

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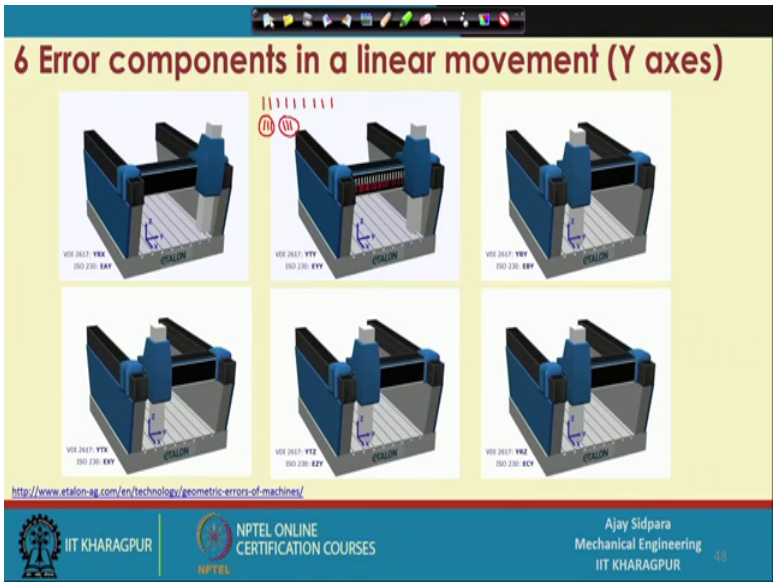

We need this spacing same for all the things, but if you see the red color, then spacing is somewhere like this, that it has accumulated one location and there is a off position and again, there is a bunching of some more. So, you are not getting a uniform motion and because of that, you are end up with more amount of forces at the end your tool, may be broken.

Here, error in the y direction, but it is around the rotation. Correct? So, this is the way it is moving. So, that rotation is happening along the Y axis. So, if plot the graph here, so, this one you consider X direction, this one is the Z direction and this one is the Y direction.

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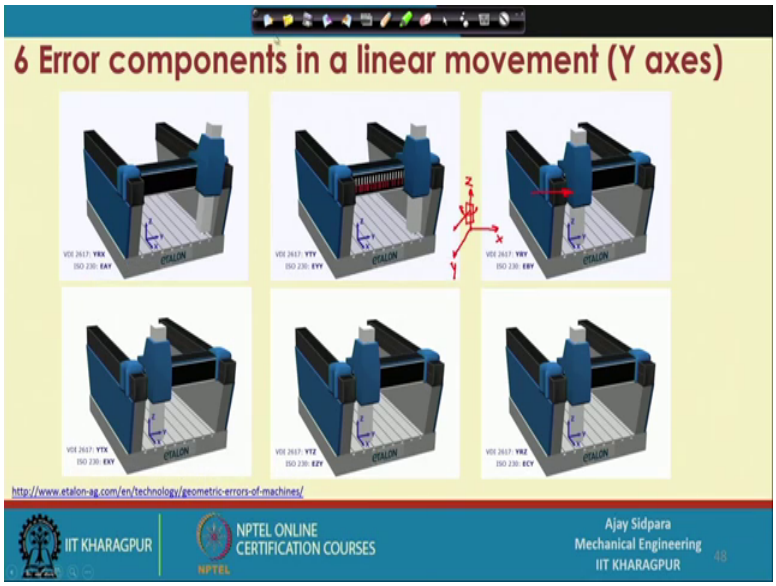

So, what is happening here? Tool is located here and this center point actually maintaining the center of this thing and then, it is swinging in this direction. I have just transformed this thing in 90 degree, so, you can get the view from this side, what we are looking we are looking from this direction, then you can get the idea.

So, let us see one more time. So, it is swinging in this to this direction. Correct? Now, it is the Y axis - Y direction and translation in the X direction. Now, you can see it is translating in this to this direction. So, that is in X direction, if you see these things. So, let us see. So, we are looking from this direction.

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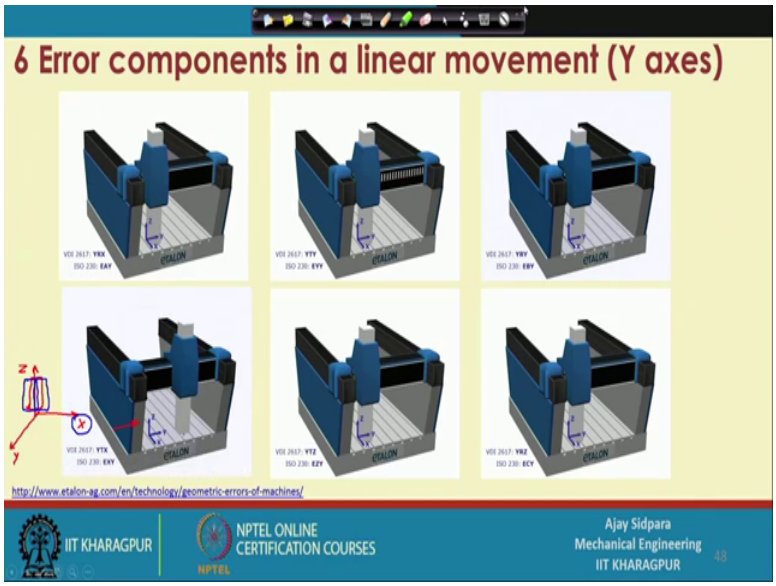

So, this is Z direction, this is X direction and this is one the Y direction and you want to keep your spindle axis here only, but because of this particular error, what is happening, that your spindle is actually moving this side or this side. It is in translation only, but it is the X direction. So now, let us see again wants to, again its moving in this direction. So, this is the translation error.

So, here direction is Y, translation in the Z axis, this spindle will move up and down now right? So, it is moving up and down. So, you are not able to get a uniform width of the uniform length when you are doing some slot cutting or some type of other machining operation. So, your surface will not be straight line and now this one is the motion in Y axis rotation around the Z axis. Correct? So, this is the rotation. So, this is what is happening, now we have to see from the top, then only it is visible. So, this one is the Y axis.

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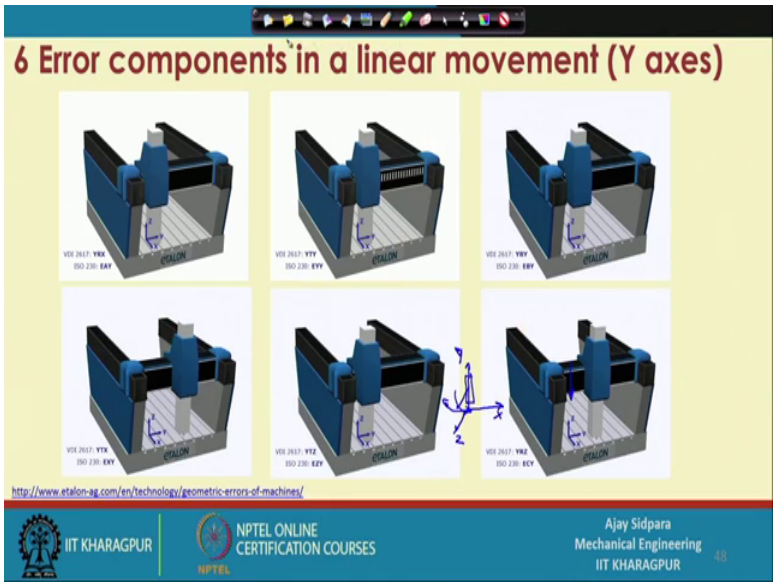

This one X, this one Y and this one is the Z axis and your spindle is located in this direction and then, it is taking this particular center and then, it is swinging in these two direction. Correct? So, these are the linear movement or linear error component of the Y axis motion.

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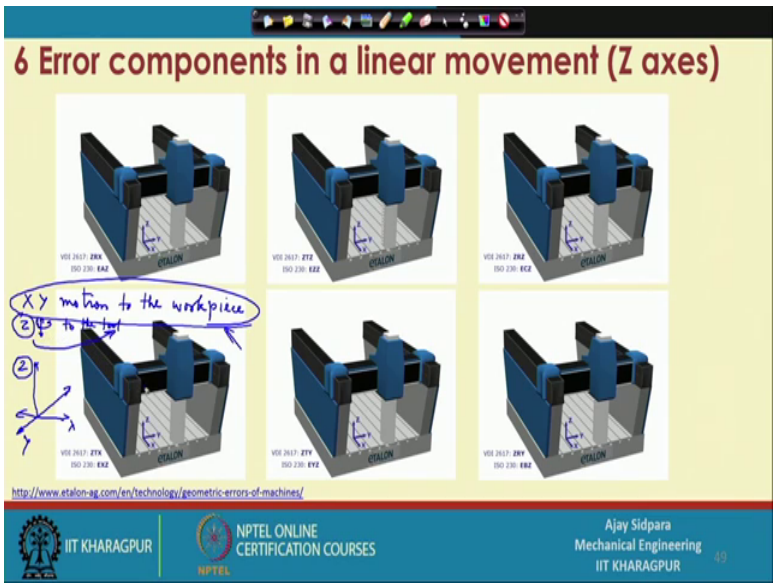

Now, coming to Z axis, now, earlier what we have seen two axes. So, those two axes are the planar axes. So, this one was the Y axis, this one was the X axis. Now, what we are talking? We are talking about the Z axis because now, earlier whatever motion we have

seen, that mostly we give X and Y motion to the work piece motion to the work piece and Z motion, that is mostly up and down motion and rotation to the tool. So, importance of the Z axis is also very - very high, that if you get some error, it will be directly connected with the tool and here, X and Y is also same thing, but it is also more connected with the work piece material because we have giving motions in X, Y direction with the work piece, but mostly Z into the tool direction.

So here, our motion is in Z direction, but rotation around the X axis. Now, you can see it is going up and down, but it is swinging around the X axis, considering this particular thing. So, this one is your Z direction and this one is your X direction and this one is your Y.

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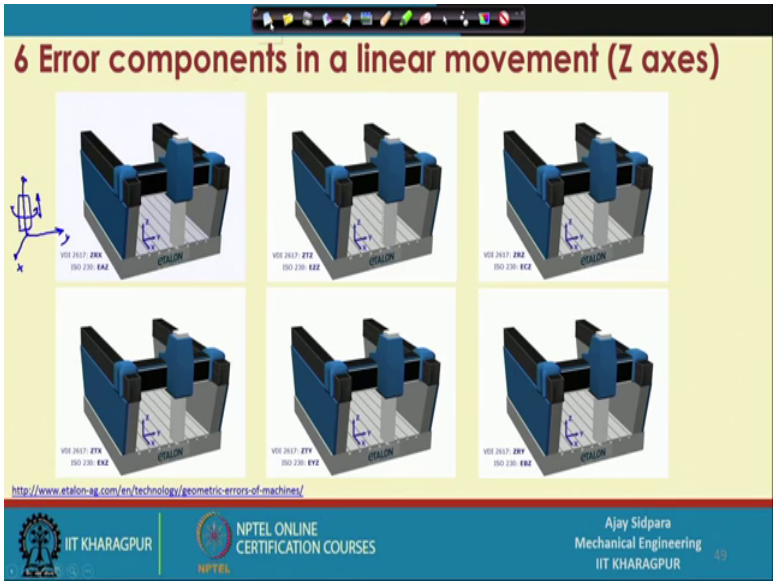

So, your spindle, when it is moving up and down it is actually swinging, that is not acceptable. Here, motion in Z direction and translation in the Z direction. So, here we are getting that white color marks. So, this mark will different when you get this type of error. Now, you can see in this particular red color, those are not uniform. So, we are not able to get a uniform motion in the depth wise, when you want to drill something or want to penetrate your tool into the work piece.

Here, it is the motion in the Z direction and rotation around the Z direction. So, this is rotating little bit in this axis. So, your tool is also rotating, but it is actually rotating in this direction. So, it is some angular displacements or angular, because of the joint

between the spindle and the tool. In this particular case, motion is in Z direction, but translation in X direction. So, it is moving in this direction. Correct? So, your tool is actually moving in this direction, when it is time to go up and down.

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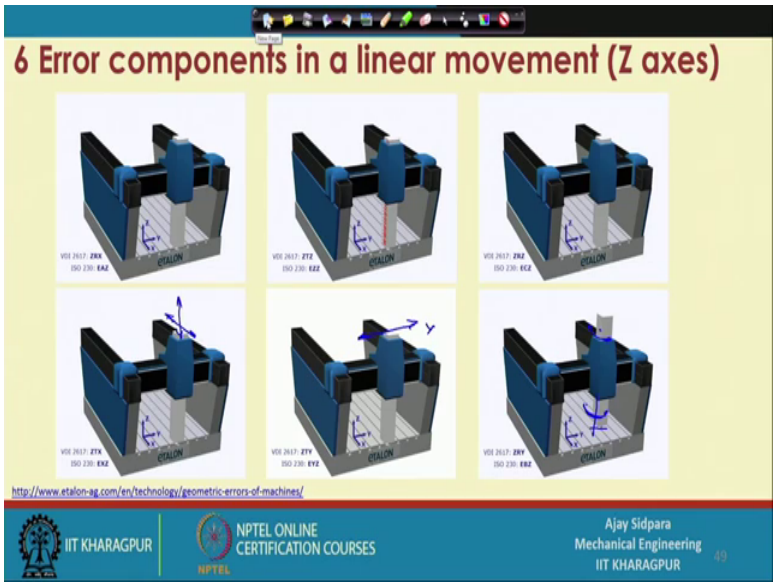

So, this is also one of the error and here same thing, but in a Y direction. Correct? So, this is moving in this direction now. So, this movement is now in this direction. This is the Y axis. Correct? So, your tool is moving in this direction. Now, this one is the Z axis motion, but rotation around the Y axis. Right? So, this is Y axis and now, it is swinging around the Y axis. So now, it is this is the Y - Z axis and this is the Y axis. So, your tool is swinging in this direction and that is center point, it is the Y axis. So, these are the different - different error component X, Y and Z direction.

So, what is the objective of learning this thing? When you do machining with such type of system, where some error exists, at the time you will always get some problem in the work piece dimension or your tool will be broken. So, you have to take care, all this things error. You may not be able to remove this error completely, but at the end what you have to minimize in such a way, that it will not create problem at the end use of the component. So, it should be within the tolerance limit or within the allowance limit. So, this is the summary of this all error. So, what these things are telling.

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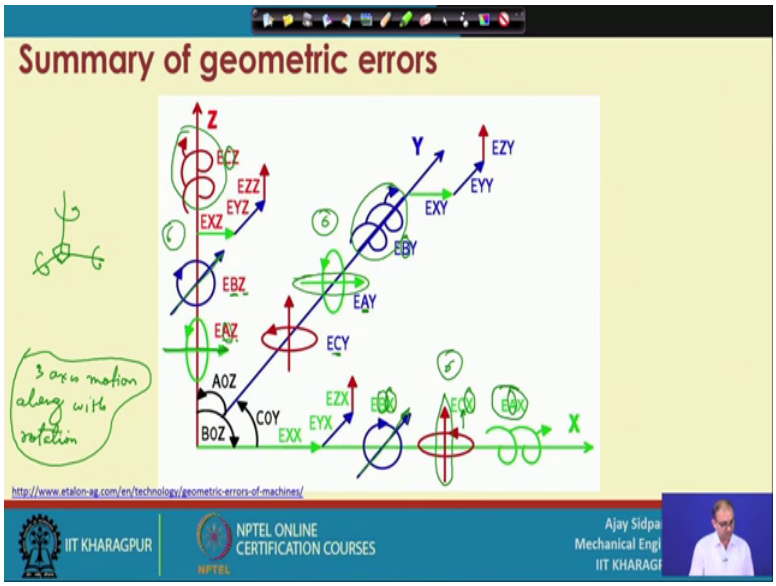

So, we have three axis, that is X axis, Y axis and Z axis. So, how many errors are possible, that is geometric error. So, first things is that who will get error, that is X error; that means, you are uniform motion, you are not able to get that is error in X direction and translation in X direction. Similar to that, we are getting the same thing in that uniform motion along the Y direction and same thing for the Z direction. Correct? So, these are the three error in the translation, in the same direction. Now, we continue translation and then, see what things are there.

Now, coming to when you are moving your slide in X direction, but you get some motion in the Y direction also. So, that is called error movement in X direction, but that is error in Y direction, that is parallel to this Y axis. So, that is why it is showing this error. Now, in the same way, your error in X direction when you are moving in Y direction; So, this particular thing is these particular axes parallel to the X axis. Same way for here, that your movement in Z direction, but it is, you are getting error in the X direction. So, that is the X direction and this is the X direction. So, this is the three different category.

Then, third one is the movement in X direction, but you are getting error in the Z direction. So, that this is shown by this error and here, it is the same way that all the axes are showing in the Z direction, but you are not moving Y direction and here also, same way in this direction. So, this all nine error are the translation error. Now, coming to the

rotational error; So, you have one rotation around the X axis. So, we know that rotation of the X axis is called A axis, rotation of the Y axis is called B axis and rotation of the Z axis is called C axis.

So, if you are rotating your object along with that direction, you may get one error because you are not able to rotate it uniformly, that we have seen in the 6 error of the rotary component. So, it also shows here this error. Similar to that, we are getting the same error in the Y direction and same error in the Z direction. So, these are the rotary axis error along the same axis, but if you are getting a rotary error in one axis, because of the presence of motion in the another axis, then you are end up with two more error. So, this is the movement rotary motion in the X direction, but you are getting the motion in the B; B is the Y axis.

So, this particular arrow, it is along the Y axis. Now, rotary motion around the X axis, but you are getting motion in the C axis and C axis is along the Z axis. So, this particular arrow is moving along the Z axis. Same way for the Y axis, you are getting a error in the A direction, that is X direction. So, your arrow is pointed toward the X direction and this arrow is pointed towards the Z direction because you are getting error in the C direction. Same way for here, that you are getting error in B direction, but your motion in Z direction. So, this arrow is parallel to the Y axis. This arrow is parallel to the X axis because you are getting a error in the A direction because of the rotation around Z axis.

So now, you can see that these are the number of errors - 6 here, 6 here and 6 here. So, when your, this is for the 3 axis motion only; 3 axis motion along with rotation. Correct. So, if you include more axis here, then your system become more and more complex. So now, what you have to take care that we have to take care about perpendicularity that means orthogonal surfaces. Correct? And then, we have to also make sure that when they rotate, at that time they should rotate along their own axis only no any type of under addition of the axis.

So, these are the geometric error which we have to consider during the fabrication of these axes of the machine.

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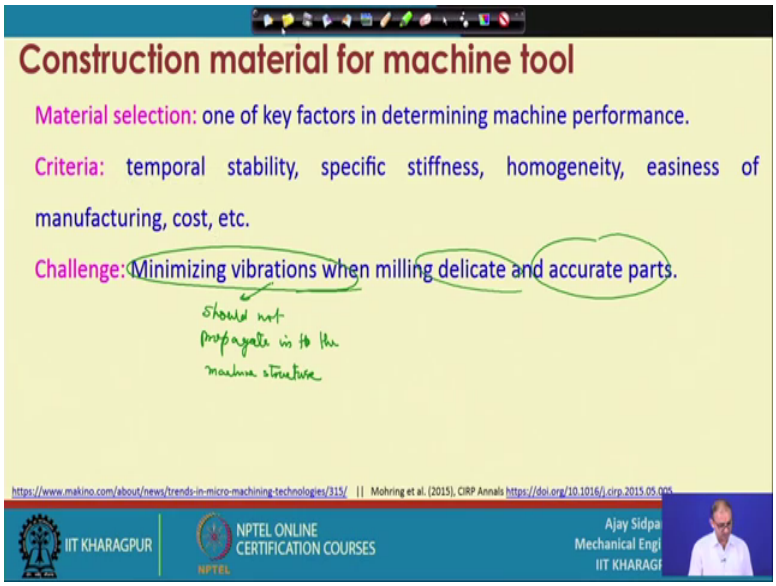

Now, we have seen that what type of configuration is required - different types of box types. There we found that meaning types of the C construction type of machine was giving more stiffness and the more load bearing capacity. Now, coming to which material we have to use for making these type of machine tool construction. So, material selection is one of the key factors in determining the machine performance. If you are using a soft material and you are look about more about cost, then what at the end? You are actually getting some error or the permanent deformation in the machine tool.

So, what should be the criteria for selection of this material? That first the temporal stability, that machine should not actually get deformed because of this static load. Only specific stiffness, because it should be stiff enough to resist or counteract the forces which is acting because of the stationery body as well as in dynamic condition also. Homogeneity is important, because when you are using one material, it should be free from defects, easy of manufacturing, because we will see some of the construction, where you have to make a very - very big casting out of that, because you have to take care about the different - different slots.

Also, you have to provide some type of ribs to reduce the weight and finally, the cost because more the stable material, more will be the cost and more it is difficult to process. So, at that time you also have to also take care about cost and many picturing aspects, when you are selecting a machine for making a machine tool structure. What are the

challenges here? Minimizing vibration, when milling delicate and accurate parts, because we know that we are working with a micro machining or the micro component, wherever depth of cut is in micron level and we are going with a very - very high speed and our tool should also rotate along its own, without any very - very high tool run out.

So, when you are talking about these thing, vibration is very - very important issue here, that is occurs because of the forces acting between the tool and work piece. So, this vibration should not propagate towards the different component; should not propagate into the machine structure. Correct? And when we are talking about the fabricating of a delicate; delicate means very - very thin or thin wall section and accurate; that means, we need a dimension as per our requirement. So, these are the challenges, when we are talking about these different types of materials. High damping will absorb more vibration during cutting.

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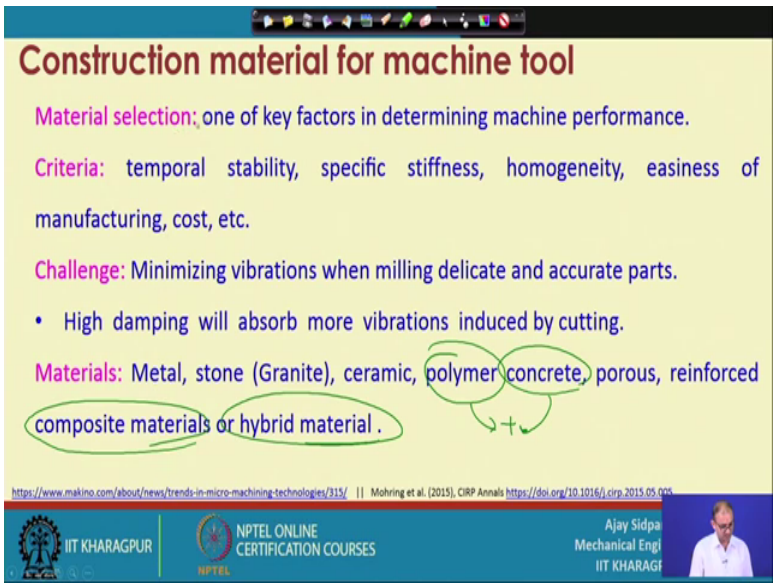

So, that is why we need a high damping material while selecting different - different types of material. So, what are the material which can be used? Metal is mostly used for conversational machining. If you see that conversational lathe machine, milling machine; mostly cast iron are used. Then, granite or different types of stones are also used. Ceramic is also preferable material. Polymer, concrete is upcoming material. Porous and reinforced composite material, because we need a porosity because we want to reduce the total weight also and composite material; that means, it is not a completely a single

material, but you are mixing actually two different material. May the two polymer or may be the different type of metal matrix composite to reduce the weight and increase the total strength.

And some cases, people go with the hybrid material; that means, you have to mix two different type of different material to get advantages property from both the materials. So, there are hybrid materials available, which will mix something like that. They are putting the concrete is a different material, polymer is the different material. So, you mix these both the things and you get one type of hybrid material. This is composite, also considered as one of the hybrid material because it compo, it consist of two or more than materials. So, you can get required property for a particular structure.

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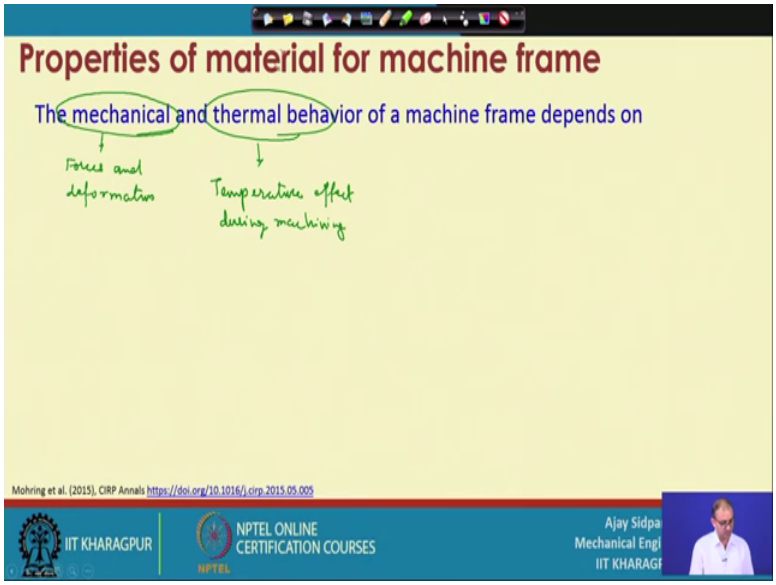

What are the properties of material you required for these things? Thermal and mechanical behavior is more important, because we know that mechanical behavior is important because we are encountering forces and deformation and thermal behavior because temperature also play an important role.

Temperature effect during machining. Correct? These are the two more important criteria based on that we have to decide that which type of properties are important for making a selecting a material for machine frame. Right?

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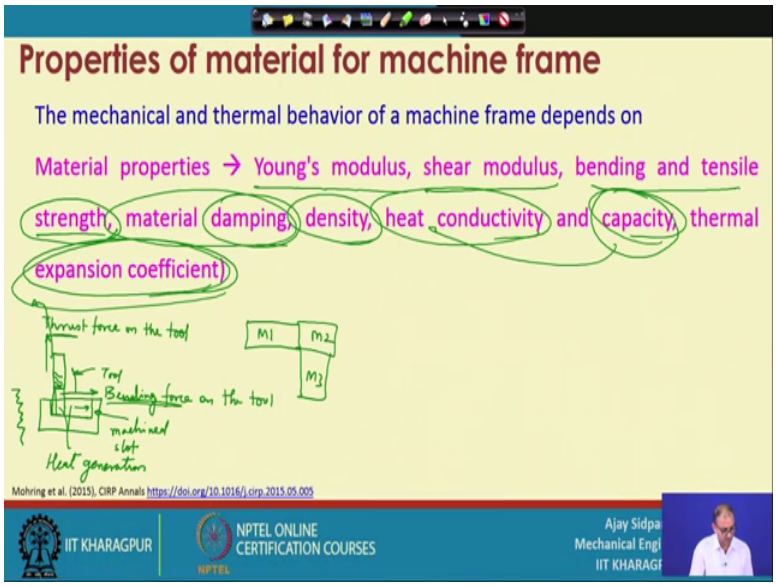

So, what are the material properties? Young modulus is one of the properties. Then, shear modulus bending and the tensile strength, because we know that we are in a different-different types machining operations. So, if you consider these things, that suppose this, is our work piece. Now, we want to cut a slot here. So, this the slot which you want to cut correct. So, what we are doing our tool is here this is the end mill cutter this is the machine slot correct. So, when you are penetrating this tool here, at that time what happens? This tool is going inside first. Correct?

So, when you are putting this thing, at that time you are putting a thrust force, because right now you are not moving the tool in the to and fro direction or considering X and Y direction. So, this force will be the thrust force and once you penetrate inside, then what you do you do? A movement in this direction; So now, thrust force action is over. Once, it is reaching to a one particular depth and then, you are going in this direction. So, then it is a bending force on the thrust force on the tool. Correct?

So, you also have to take care about these thing, that how much is your structure is stiff, because when your assembly is completely free; that means, it is more stiff. So, whatever the thrust force or the bending force, that will be propagate inside the structure; So, your material selection should be such a way that it should have high bending and the tensile strength.

Material damping; that means, when you cut the material, at that time vibrations are there; So, these vibrations should not propagate inside the structure, because it should be damp within the permissible limit or permissible travel. Density is important, because weight is also important. Lighter is the thing that is much better, but it should also should have enough strength, so, that it should not deform itself. Heat conductivity is important because when we know that when you do machining, at that time heat generated, heat generation is occur, here in this location and so that where this heat will go, that is a question because something will go to the tool, something will go to work piece and something will got the chip.

So, depending on the heat conductivity it will be absorb within that. Material capacity is important, so what is the size of the component it can cover. So, if the size of the material is very - very heat conductivity and capacity and how much heat can it store? That is related to the heat part, not the size of the component and thermal expansion and coefficient. That is also very important because we know that we are making assembly of different - different components. This is one component, this is second, this is third one and all materials are different.

So, this material one, this material two and material three and all three have different - different thermal coefficients. So, when there is a temperature difference because of the process or because of the environment, what will happen? This particular material will expand in a different - different magnitude and that is the reason that your structure also will get screwed or get deformed even before you do machining because of the presence of variable temperature in the climate.

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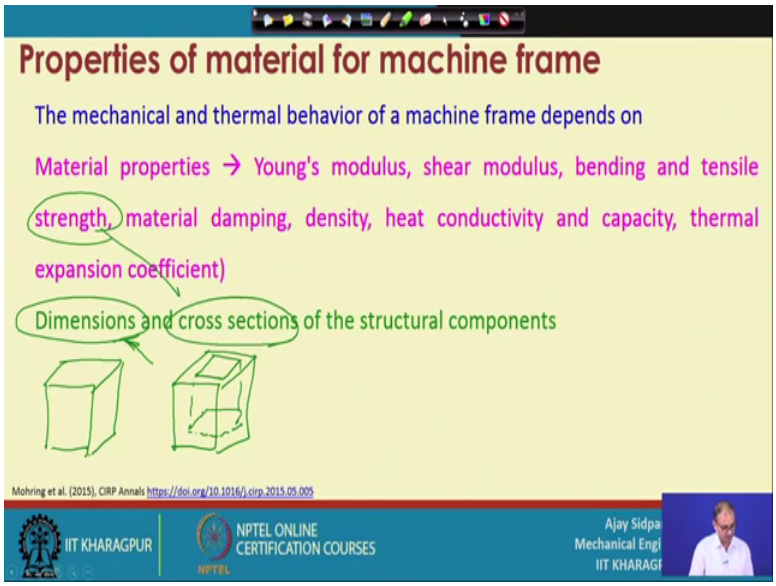

So, dimension and cross section of structural components, because that is also important how you are making this particular thing. We have seen in many cases that if the cross section is very - very fine, because suppose, you are making a solid component and you are making the same component, but a box type of structure. Correct? So, in that case, actually you can reduce the total weight of the component, but still you get the same strength based on that.

So, what should be the cross of component section of the different structure, that will decide the total weight of this part dimension; also is important because if you are going with a hollow section or something, sometimes what you have to do the dimension? You have to make it such a way that to get enough amount of strength here in this case. Right?

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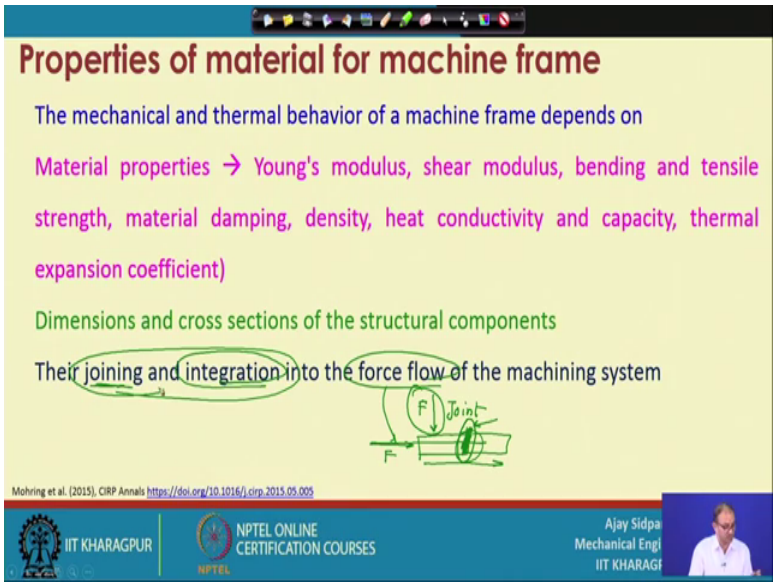

So, their joining and integration into the force flow of the machining system. So, what does it mean that suppose you have two components here and this is the joint. Correct? And if you are providing a force in this direction, what is going to happen? Then this joint will not deform because of the force, because this particular joint is perpendicular to this force direction. This is the joint and this is the force direction. Correct? So now, whole component will move in this direction.

So, no problem in that, but if this is the same thing and now, consider force is in this direction, now what is going to happen, that when you are giving a force in this direction, at that time what will happen, there these particular component; there is high chance that your joint will be in more problem because your stresses will be. This is single material for the without any type of joints. So, mostly failure will occur at this location, because it will find the where is the weakest point.

So, this is the; is the weakest point of the two material joining and you are end up with this part. So, this is called the force flow; that means, if you are aligning, you are joining and integration; the direction of the force, then it should not be any problem. So, it may not create so much of problem and your component or particular assembly will stay for a longer time.

But if there is a problem in this direction of the forces and the joint, then you cannot get this type of things which is very important here. So, you have to find out what are the

location of joint and in which direction you integrate. So, you have to find out different - different type of force flow, when you do machining. What type of force is occurs? Thrust force is there, bending force is there and because of the vibration, in which direction vibration will propagate? So, depending on that, you have to provide joining in the integration of the different - different components. Right?

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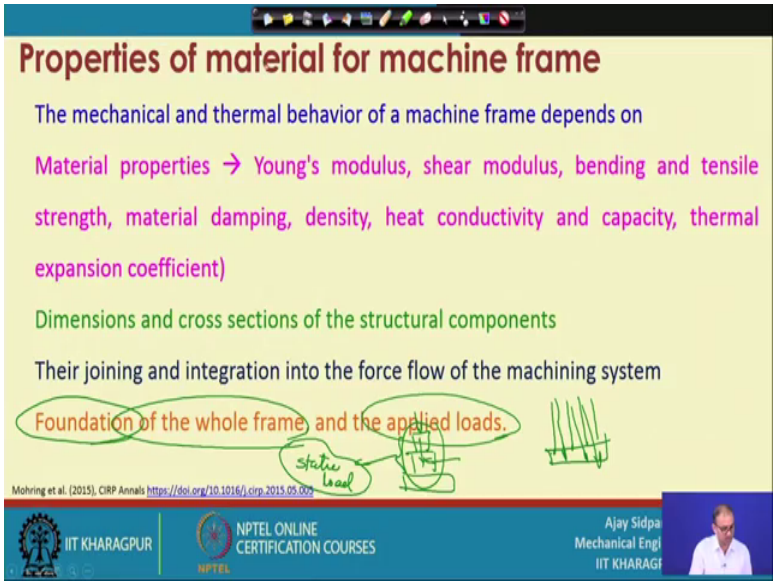

And foundation of the whole frame and the applied load, because we know that whatever is the structure, you whatever you are making on that, if your foundation is not perfect, then whole building will collapse. Correct? So, we always make the foundation very - very firm, so that it can bear more and more load on the top surface. So, foundation is very important, which material you are using for foundation and then, you are building some different components with the different material or may be the same material.

So, foundation is the whole frame is important, that which type of frame you are using and then, you have to think about how much is the loading is there, because whatever is the foundation, on the foundation you are putting a base material and on the top of work piece is there and then, all the thing will go as a load. So, these are could the static load. So, it should be at this particular static load and your foundation should deform because of that.

So now, when you do machining operation, that time we will get another additional forces, but that not be so much high, but still this static load will be very - very high and

it may create a deformation in the foundation. So, these are the things about the material property; and let me finish this lecture. We will continue this class further in the next part.

Thank you very much.