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

Lecture – 33
Components of machine tool (Contd.)

Good morning everybody and let us continue our lecture related to the Components of the Machine Tool. In the last class, we have seen the some of the different configuration of the ribs. So, that you can reduce the weight of the machine tool structure and we have also seen that we can use some of the lightweight materials, such as aluminum alloy for making some of the components, so that we can reduce the weight without sacrificing the strength of the material.

So, these type of options are very-very important to understand that how we can make the system economically, without sacrificing or without actually deviating from the required goal. So, let us continue this sub topic further. So, these things what we discussed in the last class, lightweight material and criteria for material selection that, once we know that, what is the final design and then we have to finalize that some of the properties by which, we can get the different materials out of it.

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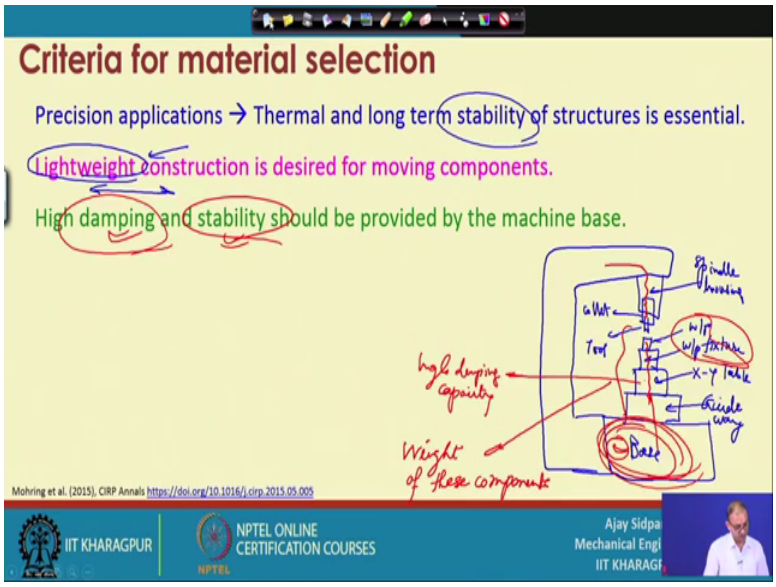

Suppose, first thing is the precision application. Suppose, your requirement is the precision, application then what we have to see that, we have to see the thermal and long

term stability of the structure that is very-very essential. So, you have to find some materials, which are not very-very, we have a less thermal copy of expansion and also you have to find something, which is rigid. So, that long term stability is important, because it will not deform by itself or because of the machining forces and later case after few years, you may get trouble out, trouble from the machines.

Lightweight construction is desired for moving components, that we have seen that, if it is not lightweight then axis movement from here to here, it will take some time, because you have to gain that in, you have to overcome inertia forces, so that you can get the required particular motion for moving from one location to another location. So, lightweight construction is important, but again you have to see that, it should be stable and it should be very-very strong, because some of time, lightweight structure are not that much stable and you may end up with the, wrong design calculation.

Then the high damping and stability should be provided to the, by the base machine, machine base. Now, what is important, because we know our base is very-very important. Now, consider this is the base. Now, what is problem if your base is no high damping or stability? Now, we know that now, we are putting the guide way here on the top on the guide way, what we have X Y table on the top. We have a work piece fixture and on the top, we have work piece correct.

This is the, static loading, whatever we are talking about and then on the other side. Now, consider this is the structure and top side, this is the spindle housing, then this the tool correct. So, now, when you do actual machine that, that time vibration will be propagated in the different-different directions correct vibration may go in these direction vibration will go in this direction also. So, that is related to the damping capacity.

So, if because now, work piece, work piece fixture. These are the external part, because this will be frequently change, depending on the selection of the work piece, X Y table guide way. These are the fix, these are the machine components. So, when you decide some material for the X Y table and the guide way material, then you have to think about the damping property, because whatever forces occurs here, in this location at that time, it will propagate from work piece to the work piece fixture and then it will go to X Y table.

So, if your X Y table has a high damping capacity then it will not propagate the, vibration further in the, this direction. It will not go in down to it, it will absorb everything within that material only. So, you have to think about that also another thing about the stability, because now, we know that these whole things are weight. So, it has some weight, weight of these components.

So, when everything is loaded on the base, at that time base will deform itself also even a static mode forget about the machining. When you do machining at that time, it will come across the static load, there was a dynamic load also. So, it should have a high damping and stability in the base material. So, your whole structure should not deform at that time, because base is the thing, which is taking most of the load out of this particular machine tool and if that is deform or it has some type of, dimensional problem, at that time that dimensional problem or the defects that will be actually replicated or reflected into the, component, which you are machining.

So, you may not get the required dimension and you are end up with that geometric error that we have seen in the different-different axis in one or two lectures before, correct.

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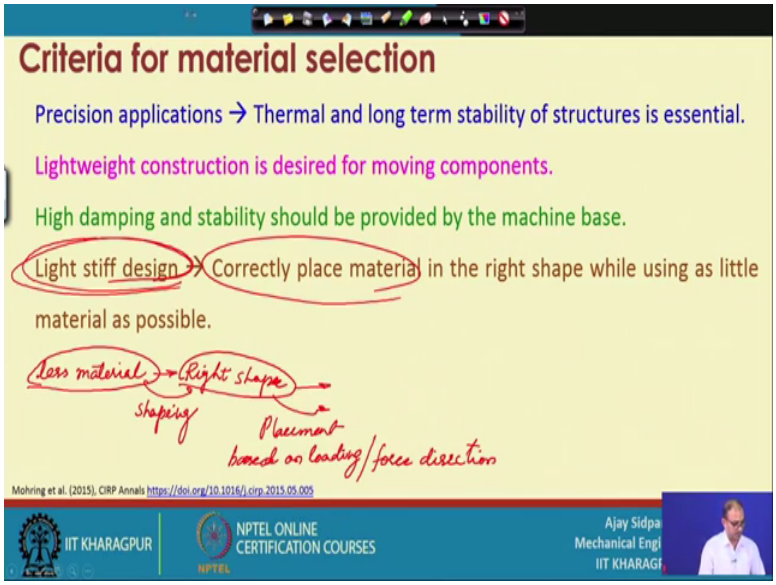

So, light and light stiff design, how you can define this correctly, place material in the right shape, while using as little material as possible. So, now, what is the criteria, for, getting these particular design that first thing that material should be less material then right shape. First, you find out the, which how much material you want to take. It should

be less material then you have to shape it, then you have to find out the, what is right shape for making that, we have seen in the different-different type of rib construction correct.

So, we have to find out the how much less material, you can use and what is the shape, which is giving more stability and that is now, where we have to place these things. So, then it is a placement correct. So, now, we have to see the, what is the loading direction. So, that is placement based on loading or force direction right. So, you have to see that, which direction you are loading. So, if you are, joint or whatever, particular material is in the same direction, then you have to see that what is the strength of the material. So, that time you have to get the light stiff design, based on this particular criteria.

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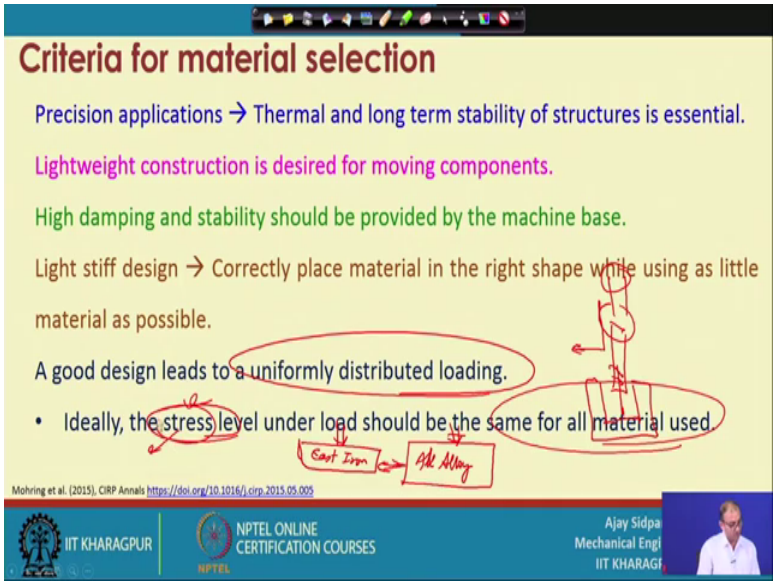

So, now what is the good design? Now, good design leads to a uniform distributed loading. Now, we know that we have a loading at one concentrated point. Now, when you do machining operation and this a work piece and when you are dealing at that time, what happens thrust forces occurring here and, because of the thrust force, it will go to the collate and collate to the spindle housing correct.

So now, when it is going from one component, another component, your distribution loading should be uniformed; that means, it should not that the one component stressed more and another component is less stressed, because if you are end up with the non

uniformed loading then one material is deform very-very, more and another material will not deform at all.

So, because of that uneven deformation, so you may get some, permanent deformation in the work piece geometrics right. So, ideally the stress level under load should be same for all the material used. Now, we have seen that, we can use different-different materials and we have also seen that one particular material is not useful for making the whole system or the whole machine.

So, we are using different material at different-different location for making different components and, because of that all materials have different properties and that different properties are creating different stress level and we have to make sure that the, whatever stress is, are generated, it should be same for all material that, we have seen in the last class, there if one is the making of, this is the cast iron then if you are using a aluminum then actually you can increase the size of the component.

So, this is the aluminum alloy, you can increase the AOL, volume then actually, you can maintain the stress level under the same loading. So, whatever loading is here, if you are making this cast iron size and the aluminum size same then aluminum will be more stressed compared to cast iron, but if you keep the area little bit high in such a way, that your total load or the total weight is not increased, but these are, these are equal then actually you can maintain the stress level in the different-different components right.

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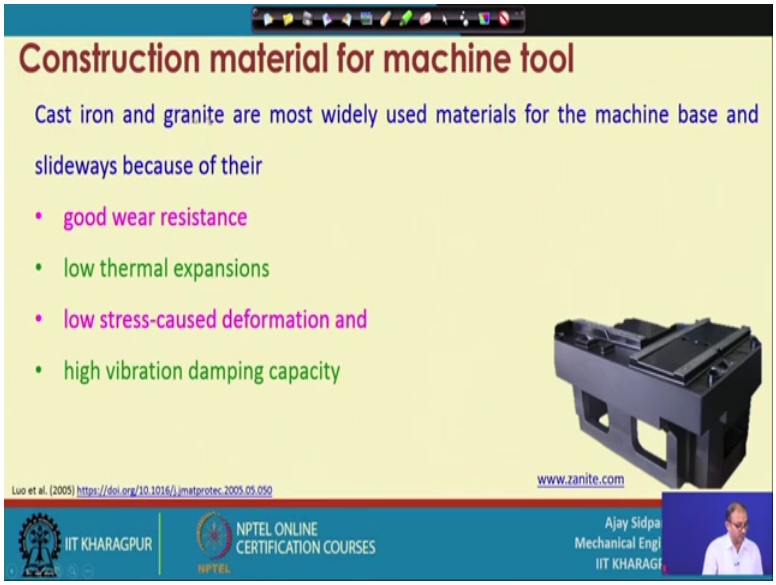

So, now construction material for the machine tools, now, this is one of the, base of the machines. Now, what are the materials are mostly cast iorn and granite are most widely used materials, for machine base and slide ways, because of their some of the properties. It is one, is the good wear resistance, because if you see all the conventional lathe machine and the milling machine, your base, you will find the cast iron granite is next to cast iron, which is also widely used low thermal expansion, because even if there is a temperature difference in the climate.

Because mostly when you install a conventional lathe machine or milling machine generally, you do not provide the, an alloy upon the top, because of that what happens, that whenever you operating in a summer or your operating in a winter temperature difference is more than 34 degrees in some of the locations. So, because of that you may not get, large variation in the thermal deformation, because of the climate temperature difference.

Low stress caused deformation, because when you are using this material, this material have subjected to less deformation, when under, stress and the high vibration damping capacity. So, whenever there is a vibration, this vibration will be propagated or it will be absorb within this end only. It will not actually task for another component or other joint. So, these are the some of the, advantages of these particular materials.

So, that you can use, it comfortably for the different-different applications, but some of the issues are there when you are going to use, these material for the, micro machining center, because right now, these are widely used for conventional machining, where we are not looking, at the detail at micron level or 10s of micron level, but whenever component and the machining parameters setting. It considered as a micron accuracy or sub micron accuracy, this material selection will play a important role in the construction.

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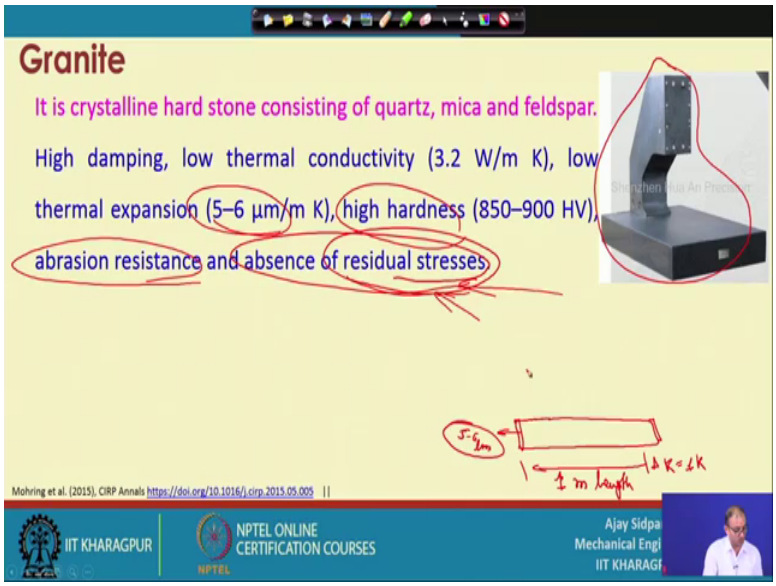

So, let us see those things. So, this is the granite. So, granite base is very very useful compare to the cast iron, because it is a crystalline hard stone, consisting of quartz mica and the feldspar. So, combination of these things are consider, called as a granite structure. What are the important properties? It has high damping; that means, whatever vibration are there it will absorb itself. It will not propagate or it will not transfer to the another material.

Low thermal conductivity, it is third point, 2 watt for meter Kelvin low thermal expansion. So, it will expand 5 to 6 micron per meter in a per degree of Kelvin change. So, if you consider any component. Suppose, this is one component and this is one meter of length, one meter length and this a, temperature is changed to delta K is 1 K ok. So, whatever is this 1 K, whatever change you will get, you will change, will get in terms of value matric change, you get 5 to 6 micron correct.

So, this reasonably good for certain components, but you are talking about a micro machining, where sometimes your depth of itself is in the 5 to 6 micron, at that time, it may create some problem at the later stage, high hardness is the one of the parameters by which you can select these things, for a, micro machine or some, reasonably good micro machines parts. Abrasion resistance is there and absence of residual stresses, because if you make a component from the, cast iron or some other steel material, at that time you have to actually machine those components correct and if, when you do machining at

that time there is a cutting forces include if you go by a casting process or powder metallurgy.

There residual stresses, you have to relieve before you use for end operation, but here you will not get residual stresses that is one of the advantages. So, that you do not need to post process the, whatever structure you have fabricated out of the granite, but we, same thing you have to do for the cast iron, because after once the processing of this particular structure is over, you have to pass through the, stress relieving operation. So, that it should not create any problem at the later stage.

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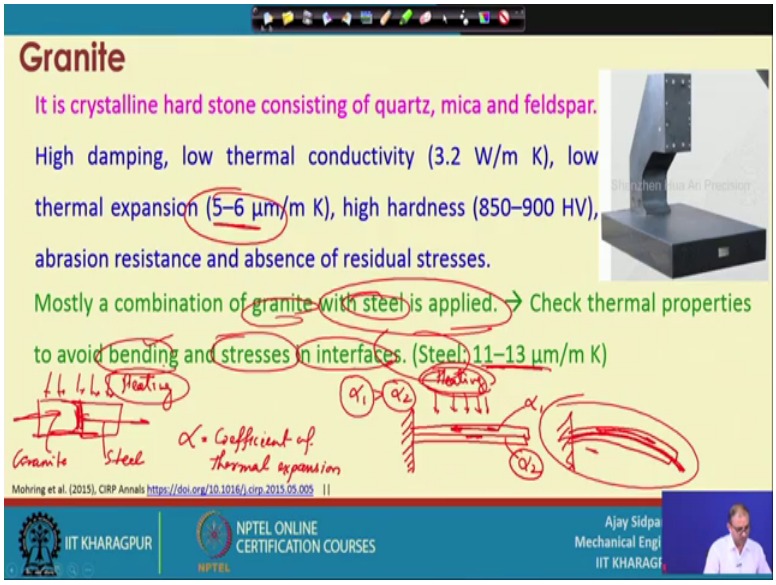

But if you see the granite, granite is also used for, combining with the steel material or some other materials. So, now, if that is the case then, what you have to do that you have to check the thermal properties to avoid bending and stresses at the interface. Now, consider, now, steel has a, coefficient of thermal expansion 11 to 13, but it, this particular thing is a 5 to 6 only. Now, see how these things will make difference. Now, consider let us take one example that you have a two strip. This is the two strip and this one has a alpha 1 and this one has a alpha 2 ok.

So, alpha is the coefficient of thermal expansion and consider alpha 1 is higher than alpha 2. Now, you heat this component. So, this is the interface. Now, you are heating ok. Now, we know that alpha 1 is has high coefficient of thermal expansion. So, this will expand or it will response very quickly to the temperature change, but now, what is our

(Refer Time: 15:52), we wants to keep these things straight, but now, if this is the temperature, then what is happens that finally, you are end up with the bending of these thing correct, because this will start expanding, but this will not respond quickly, because it has a low thermal expansion.

So, it will be remaining within that particular strength only, where is expand, where, where it is expanding, but this will respond to more to the temperature. So, this will bend, because now, it is more expanded. So, now, what is happening here in this particular case? Now, if you have two material, one is stainless steel and another is granite and you have interface ok. So, this the granite and this is a steel. Now, again you are a, this both the components are subjected to the heat.

Now, what is going to happen? Your steel will expand more, compare to the granite right. So, when you are utilizing or using the combination of this thing; that means, you are keeping a both the things together, granite and the steel. At that time you have to make sure that temperature is not very-very fluctuating within that particular system. Even there is a 1 degree or less than 1 degree, change that is enough to create some problem at the interface or it will create a bending that is, because of these particular things.

Now, if you see, if it is bending more, then what will happen? Interface will be different. Now, these interfaces make create some problem, because now, it will sleep along with this interface, because material is deforming or sliding on another face, because of the temperature deferent. So, bending is one of the case and the stresses will be there in the interface and finally, joint will be loose and that is what you want to avoid for the long period of time. So, that is what is in terms of granite.

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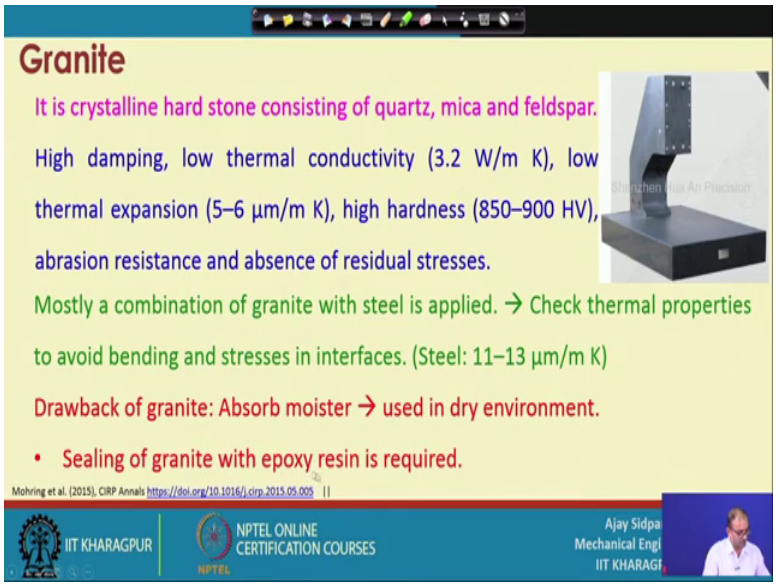

So, what is the drawback? drawback of the granite, it absorbs the moister, because when you are using this in some types of humid environment, where the temperature, you are maintaining temperature, but humidity is very-very high, then it is creating problem. So, where it is creating? When it is humid, humid at that time, it will become very sticky. So, when you are using granite as a micro machining machine tool construction, but real at that time the moister will create important, but there is one of the, remedy is either, you use into dry environment, you maintain the humidity below a permissible limit.

So, that steel you can use the granite or other thing, what you can do? You provide the sealing of the granite with a epoxy resin. So, once you make this components then what you do? You provide the epoxy resin. So, whatever moister is there, moister will not come into contact with the granite and you can actually, keep this particular structure safe against the high moister.

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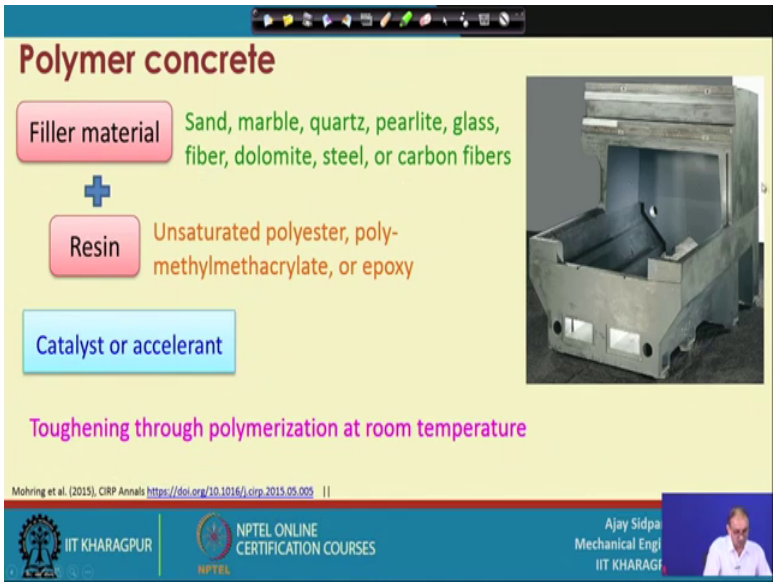

Then another motive is polymer concrete. So, this is the complete structure, one of the structure by which you can make the, monolithic structure. So, now, what things are there that, suppose, here what equency, that here what one guide way is given here, that is the inbuilt here. So, you may get 1 X axis in this direction. Now, these are the two guide ways are given here and in this you will mount another guide ways for moving in the Y axis here and on the top of that or here also you are providing 2 location, where bolts are there.

So, may be the z axis is coming from this particular location. So, you can see that many things you have to provided you have to provide in this particular structure so that at the end you do not need to deal also. So, many times when we are casting such a big things at that time you provide some of the things very comfortably. So, you do not need to do any type of extra machining for making those particular thing

So, let us see what is polymer concrete as polymer concrete consists of filler material. So, what are the filler material sand, marbles, quartz, pearlite, glass, fiber dolomite steel or the carbon fibers. So, these are the filler material. So, you have to mix this filler material for the resin. So, if you mix two thing what are the resins unsaturated polyester, poly methyl, methacrylate or epoxy. So, you mix these two things in the catalyst or the accelerant. So, what is the role of this catalyst or accelerant they will keep the properties of this particular materials intend.

So, you this thing will change when you are actually processing those things and it will also avoid the effect of the external parameters temperature or may be the humidity or other things, it will not create any problem. So, you have to add some type of catalyst or accelerant which will actually increase the probability of proper mixing of those two things and it will also reduce the total time.

And all things you have to do at the room temperature. So, once you make two things fix, mix it along with catalyst and there is polymerize happens between these, all the three things and then it becomes very very tough.

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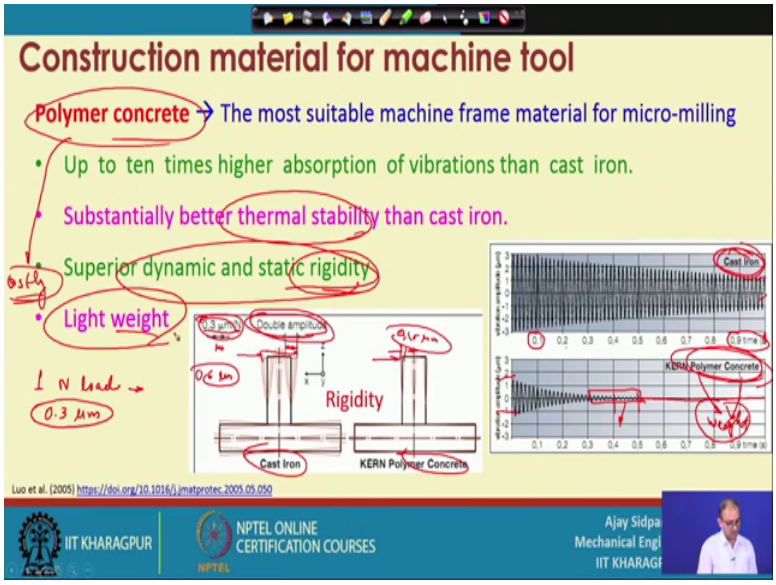

So, this is the way you can make the polymer concrete. So, polymer concrete is the most suitable of machine frame material for the micro milling process. So, why it is so, let us see the, so it is up to 10 times higher absorption of vibrations then the cast iron. So, this is one of the example, so of kern machine. So, that machine we will see the demonstration some time later.

So, this is the vibration amplitude in the cast iron. So, this is the cast iron and this is the vibration amplitude and time is in terms of the 0.1 seconds. So, this 0.1, 0.2, 0.3 and this vibration level in plus 2 minus 3 micron. Now if you see that when there is a vibration of this particular magnitude, it is a 6 magnitude 6 micro magnitude plus or minus 3. Then what is happening here that it is not actually diminishing to the 0, even after one full

second. Now you consider this is 9 and this 1 second after 1 second, still it is there and if you actually extra pull it this particular graph, it may continue for another 1 second.

So, after 2 second or 3 second you may get a vibration diminish, but if you see the polymer concrete. Now initially with the same loading your first thing is, your load getting is enough vibration here right. So, it will absorb and within plus or minus 1 micro. What is going to happen there within 0.4 or 0.5 micron, your vibration is almost zero in this case and sometime what happens, this particular vibration also may not create any problem, because it is within that particular acceptable limit of the machine tool and that is the advantage of using polymer concrete for a structure material in place of cast iron or the granite material.

Because both have some disadvantages and polymer concrete is actually overcome all the disadvantages of the cast iron and the granite material substantially better thermal stability than the cast iron superior dynamic and static rigidity and the light weight, because now you are using the polymer and concrete is, polymer is actually the one of the components which is very very light in weight and the here cast iron a.

Even granite, you are using most, it is stone based thing and you are not mixing anything there. So, its weight is also very high cast iron is actually metallic component. So; obviously, its weight is very very high, but here concrete is one of the components which weight may be high, but you are using polymer also. So, depending on the proportion of the polymer and the cast concrete at that time that depends on the what is the total weight of the polymer concrete correct

So, that is the lightweight superior dynamic and static rigidity that is also important. So, now, this is the one of the graph it is showing. So, this is the cast iron and now whatever we are putting that per Newton, there is a, there is a deviation with a 0.5 0.3 microns. So, if you provide 1 Newton load then you will get the deformation of 0.3 micron. So, that is bending movement or may be the thrust force or whatever way you are putting. So, if you are providing this, this is the scale of that. This much is the scale of a this part.

So, when you are putting a load in this direction or impact in this direction what is happening that this particular thing will is not very very rigid in structure. So, now, if you see this much is the vibration or this much is the deformation (Refer Time: 24:46) that deformation it is in a double the amplitude, see it is double than these things. So, that is

why it is showing 0.6 micron in both the cases, in this two, these cases so that is not the correct way, but if you provide the same loading or impacting this polymer concrete. Now you can see that it is not even half of these thing.

So, 0.15 micron or something is there and that is the advantage of using polymer concrete for the machine tool structure. Now, these are some one of that, some of the advantages other than that what you can get, you can get the long term stability and this long term stability is very important, because when you are using at micro scale machining, at that time what you are end up that after 6 months or after 1 year the machine is not behaving, as it should behave after some usage.

So, if you are using a polymer concrete material even though it very costly, it is costly, but the cost is actually compensated by the precision and whatever the rigidity you are getting and thermal stability, whatever you are getting compare to the other parts. So, that is one of the advantages why you are using costly material, but still it is compensated, cost is compensated with respect to the different-different parameter and the long term stability of the machine tool.

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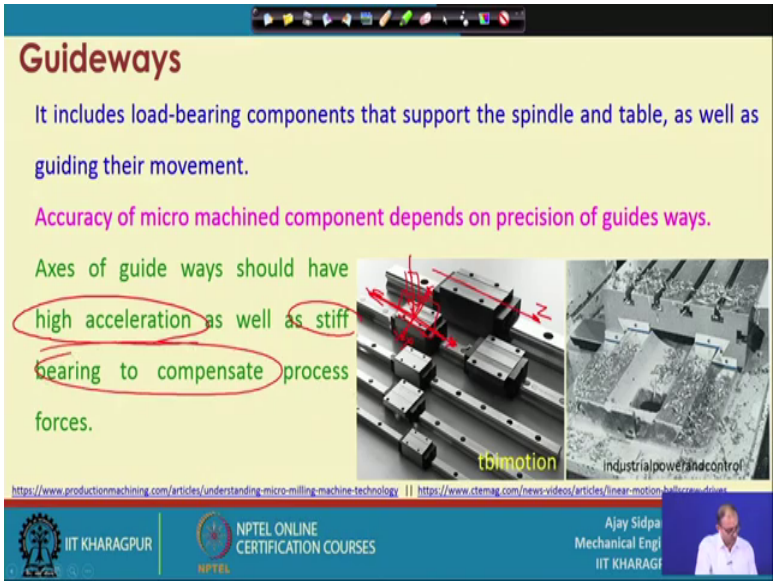

Now, coming to the guide ways; so now, what are the guide ways? So, guide ways; that means, on which you are putting all the components. If you are using a spindle then the on the spindle you are putting these guide way, because you have to move z axis in this direction. So, this will be the z axis when you are mounting vertical and if it is in a x y

table, then it will be, you need two in this case. So, one is moving in x direction, one is moving in y direction and then you are guiding that movement particular in different-different directions. So, these are the two things.

So, this is the linier guide way, these are the box type guide ways. So, here everything is depend of that how far, how much you are moving in this direction. So, accuracy of micro machine components depend on the precision of the guide ways. So, now, if you see this things, this is mostly you will find in the large capacity machines and that is not the case. In the micro machine the axes of guide ways should have high acceleration as well as stiff bearing to compensate the forces, because now see if you are using this thing for x and y direction, then what will happen your z axis will come here, your tool will be here and you have a work piece and everything located at this location.

So, when you are moving in x direction or y direction you have to actually encounter first is the acceleration, how quickly you are moving your work piece in these two direction under the effect of forces. That means, when you do machining with high depth of Kert you will end up with the more machining forces or you are going with the high feed rate, then again you can get the more forces in the machining process. So, it should have high acceleration, because you quickly want to complete the particular processing step, but it should have high stiff bearing or the overall stiffness. Let us not consider only bearing only, overall stiffness is more important, so that it can compensate the forces which are acting during the machining operation. So, in the next lecture what we will see.

We will continue this guide way that what are the different guide ways and which guide way we can use for the micro machining center that will cover in the next class.

Thank you very much.