Introduction to Mechanical Micro Machining.

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Lecture – 47
Components of machine tool (Contd.)

Good morning everybody welcome again to our course on mechanical micromachining introduction, now in the last class we have seen that there are different type of bearing we can use for making a system of a spindles here. And we have found that ceramic bearing or we can consider the hybrid ceramic bearings are more useful or more advantages to use in the spindle system, because they have lot of advantages compared to the steel ball bearing.

And we also seen that there are different ways to use this ceramic bearing; that means, if it is a hybrid ceramic; that means, we are using bowl only of a ceramic material, but still the races are made of stainless steel or the sum other steel materials and we have also seen that there are bearings available which are completely made of ceramic; that means, inner res outer res as well as bowls all are made of ceramics.

So, those have very more amounts of advantages because they are more suitable for a very high speed applications and where the heat dissipation is a issue. So, let us continue our topic further on this direction. So, we have discussed about hybrid ceramic bearing and we have done some work about this aerostatic bearing long time before that is aerostatic guide ways.

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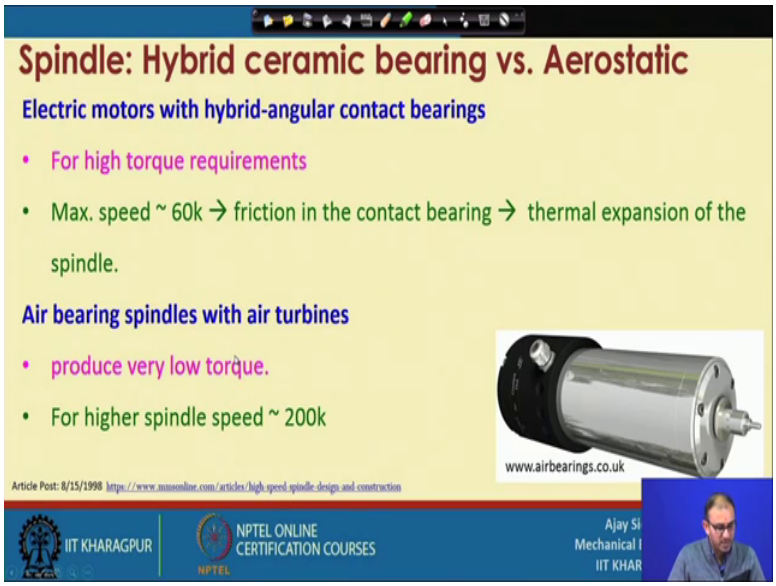

That means what we have discussed that that time that there are some of the ways by which we can move the component in x y and z direction at that time we have considered a this aerostatic guide ways, but we can also make bearing also in a aerostatic way.

So, that we can make our system more and more friction less and wear less, so let us discuss this thing. So, now, here the first thing is the electric motor with hybrid angular contact bear bearing. So, here what we are doing that this is mostly used for the high torque requirement; that means, whatever we have discussed in the last class or the before the last class we were discussing about the bearings where we are using ball or the cylindrical roller bearing for motion transfer right.

So, it is the electrical motor we are using there and this is a hybrid angular contact bearing. So, we are using ceramic as a one of the material for balls and then this is are made of steel, and here the what is the issue here that we can mostly go with the a maximum speed of a 6000 rpm, because here also even though we are telling that there is a less amount of contact or still there is a contact.

So, whenever there is a contact let it be line contact or the point contact we always get a friction and that friction in the contact bearing we will actually create a problem when we go with a rpm more than 6000 or something like that. So, what is the problem that it will become a more problem related with thermal expansion, the thermal expansion of

the spindle will occur and because of that you may not get the required accuracy in the machining processes.

And so what is the solution for that that instead of this particular contact bearing we can use air bearing with a air spindle. So, here what is the thing that this is one of the general view of aerospace air bearing system, so here we have to supply air. So, that that shaft and the outer periphery should be separated by a film of air instead of a ball or any other type of media.

So, what is the advantages here that advantage are that you can go with a speed of a 2 lakhs rpm, even spindles are to 5 5 lakhs rpm with steel under research state, but somewhat is somewhere reported that they already made this step of bearings this step of spindle where it will it runs at a 5 lakhs rpm, but it produces very low torque because when you go with a extremely high rpm at the time you have to scarifies with the torque, but still the torque is enough to use for micro machining operation, because we know that our depth of cut is very, very small and we actually go with a very, very low fitted in this case and our rpm is very, very high.

So, in this particular case it is no it should not be any issue that torque is very, very low. So, we can use actually aerostatic bearing or aerostatic spindle for machining of a different, different kind of materials.

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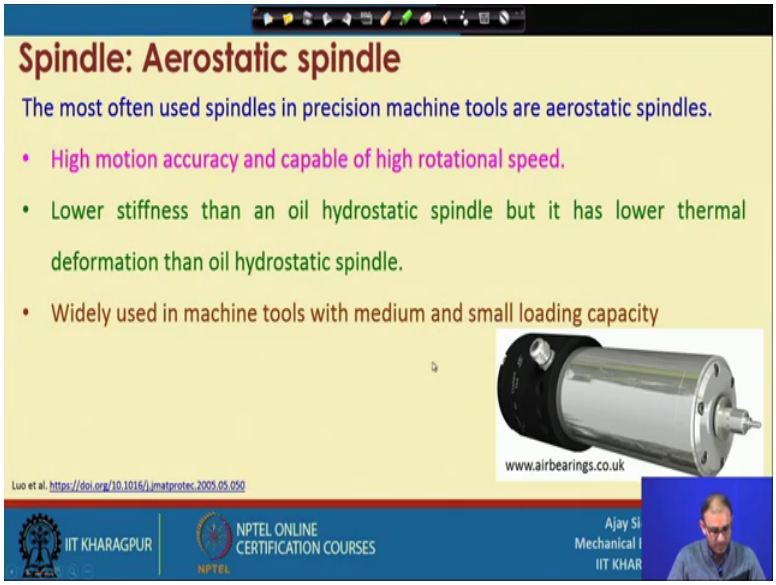

So, this is the most often used spindle for high precision machine tools are mostly that is called aerostatic spindle, why it is used because it has a high motion accuracy and a capable of high rotational speed that we have seen that you can actually because of the air film that you are not able to get any contact between the two relative motion surfaces, and because of that there is no wear and tear of any components and you can go with a speed depending on the supply of air and water the other accessories attach with the spindle.

So, your requirement for a high speed rotation high rotational speed is fulfilled by this particular aerostatic spindles. It has a lower stiffness than the oil hydrostatic spindle because here the oil is a highly viscous that the time you can actually play around the stiffness very high.

But that low stiffness actually it is not an issue, but it has a very low thermal deformation then the hydrostatic bearing hydrostatic spindle. So, here this is one of the downside of this particular spindle compare to hydrostatic and mostly generally we do not go with the hydrostatic spindle in the high speed machining or a micro machining centre because this a load carrying capacity is very, very high in this particular case, but our case it is not the issue.

So, that is why we generally go with the hydrostatic spindle for micro machining operation right. So, it is widely use for the machine tool with a high and the medium load carrying capacity because that is where particular micromachining field is fitting in that because our load is not very, very high, but it considered as a medium and the small load capacities.

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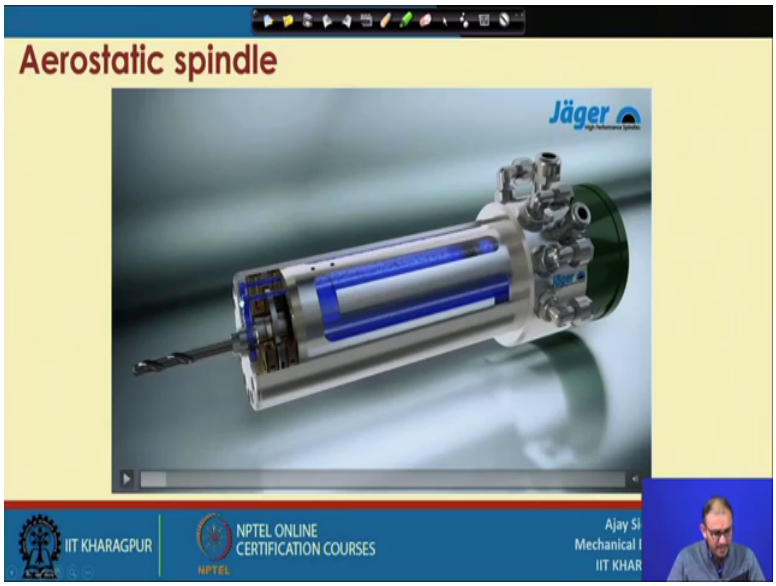

So, now let us see this thing that what things are there inside it. So, this is the one particular aerostatic spindle, and this tool is at a at this location and these are the different, different opening by which you can if you supply the air and then other than supply there you have to apply cooling also in some of the location. So, you will get the different part as well as you need a electrical connection.

So, some of these things are the wires for rotating the motor which is actually inbuilt inside this particular spindle right. So, this is the circulation general or circulation passage of a air supply. So, here you can get the air is actually going up to the nose of the cutting tool holder. So, it is also possible to cool this particular thing or create a some type of sensing element here in this remaining part is given for the air bearing which is located at this location.

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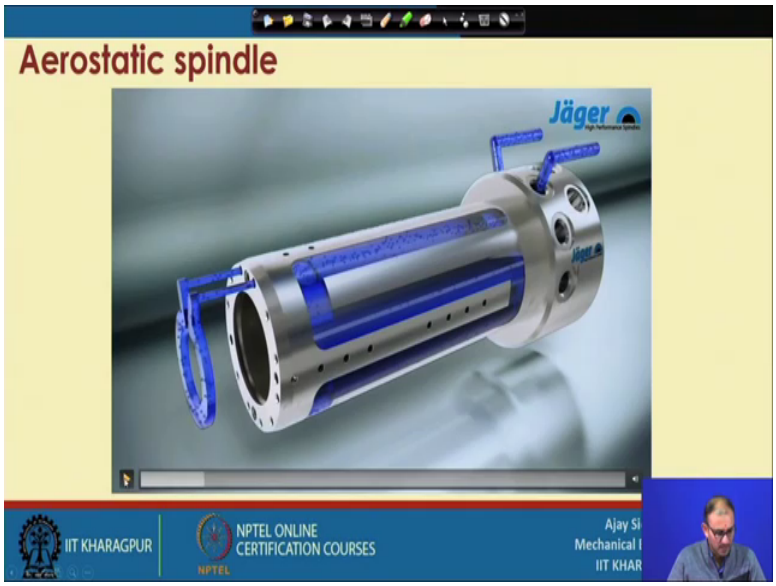

So, this is you consider as a close loop continuously because we can see that you are note actually dispensing this air into the atmosphere in one direction you come one way you can say that this air is going inside the system and this air is going outside of the system correct.

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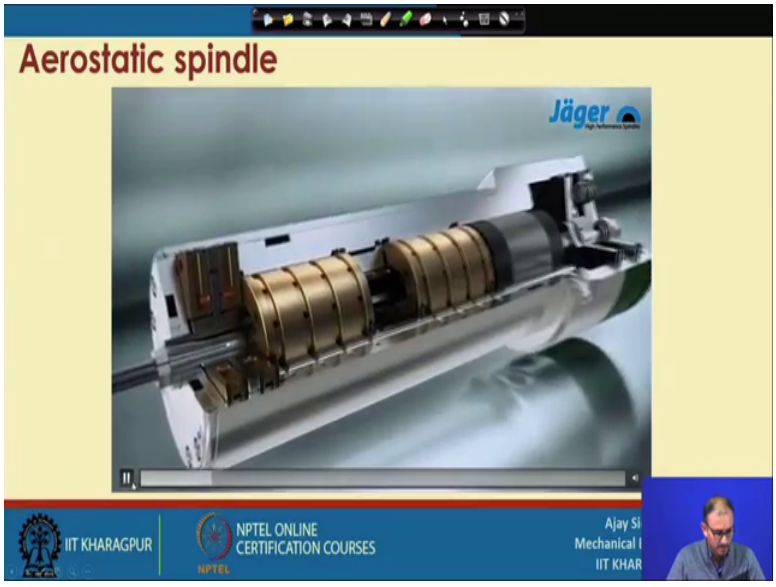

Now, you can say that you will note find any type of ball bearing or any other type of bearing because this bearing is a air bearing. So, instead of ball another thing that you will get some passages here. So, through with this whatever air is coming into the system

that air will actually passed through this particular sockets or passages and then it will actually create a uniform pressure around the shaft right, so this is the passage for air.

Now, you can see air is going through this particular passages and whenever there is opening through this happening it will actually enter radially towards the shaft.

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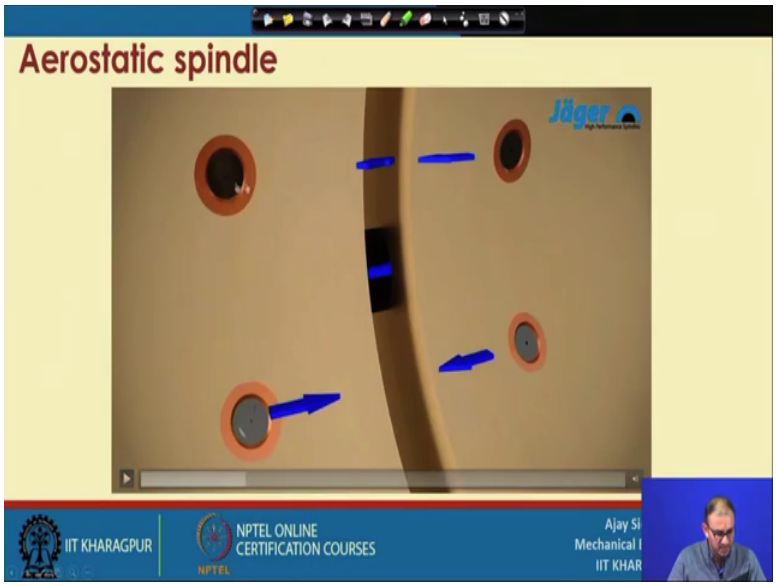

So, this is the inside view of that and you can see here, so this is the inlet and this is the outlet; that means, through which the it is went consider and this went again go through this particular outer periphery and then it will be collected through that pi which was shown in the few second before.

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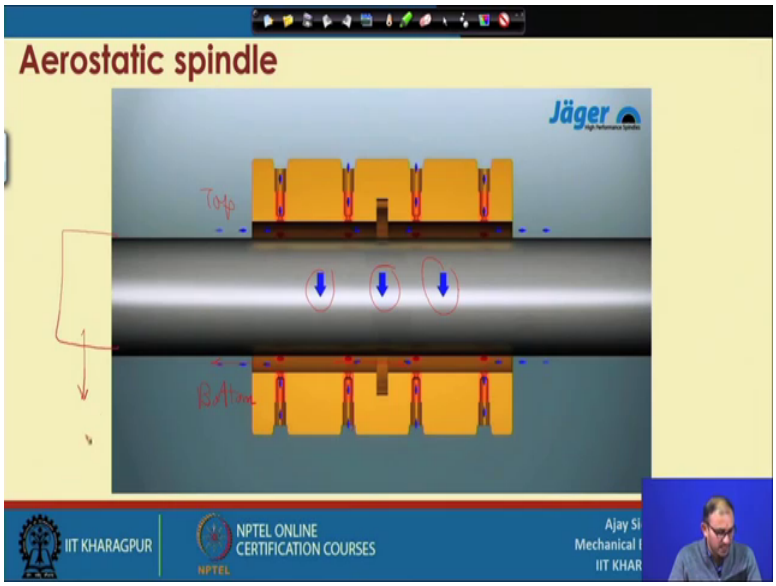

So, this is the side view and now we have seen this thing long few lectures before that it has a very, very high radial stiffness, because when it is going down because now suppose your tool is located here. At this location and then you are getting a force from this direction, so you are actually going moving in this.

So, you are getting force here in this direction, so this is the force. So, when there is a force now you can see right now the whatever this air coming through this all has the same colour; that means, blue colour is there. So, it has a same pressure on both the side that is on the top side and this is on the bottom side correct.

So, it does not have so much of variation, but when it is under operation; that means, you may get a radial load in the different, different machining operation. So, at that time what is going to happen right, so now, load is increasing in this direction now you can say whatever air is coming from this location it is in red colour; that means, here you are not getting enough area here.

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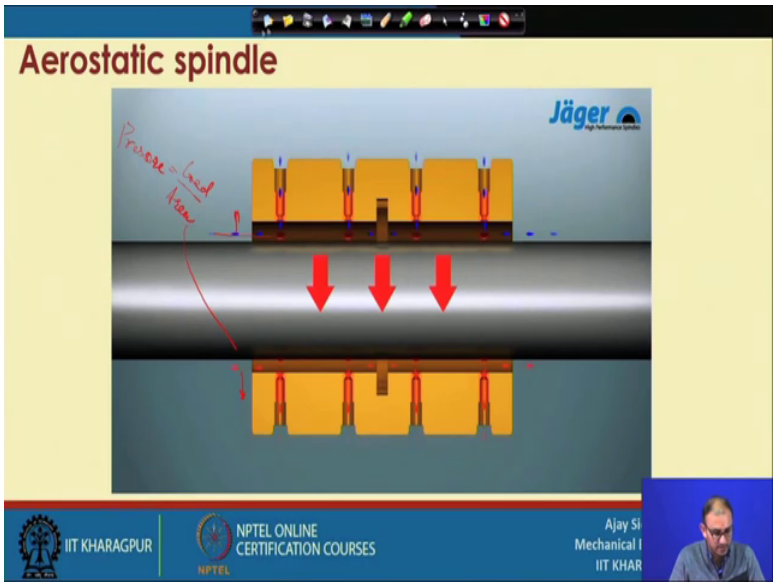

So, we know the pressure equal to load by area, so here area is reducing here at the time because of that what is happening the your pressure is increases this location when it is going down you can see that here area is increased. So, because of the higher area pressure equal to load by area correct. So, now, here area is this location area is high and this location area is less. So, because of that here the pressure now you have a large area.

So, you will not get so much of pressure here, but here it is small area. So, you if pressure will be increase from this location right. So, because of that problem what is happening that you will get a, because of that again the shaft will go to the centre position again it will try to stabilize the pressure on both the sides. So, now, it is coming back again this location if it is again increasing then pressure will again the difference differentiate between these two part and then again you will get the part.

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So, this is the top view; that means, from the bottom of this cross may is it is a axial cross section here. So, here again if it is from this lower direction your shaft is moving towards down then.

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Your pressure will be different here, so on the upper of there is a low pressure and lower up there is a high pressure. So, whatever this red colour syringe or the nozzles are showing this will create more amount of pressure here and here this blue colour has the less pressure. So, because of this pressure difference again you particular shaft will again

be in the centre position. So, that you can avoid this particular pressure difference correct.

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So, this is the way actually you will get the radial stiffness, and we know that this radial stiffness is very important when you do the milling operation.

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Now, we have seen here the it was the radially actually a lancer, so radial stiffness was very high and now this is about the axial stiffness, because when you want to drill something then you are plunging your tool into the work piece. So, it has a axial

movement in this direction. So, let us see that how it will compensate for the axial movement now see here right now this is the things which is attached with the tool holder. So, this is the part of them this is the system which is the which is coupled with the spindle system and this air supply is coming from here and then it is dissipated from this two direction right.

So, this is the open position where the air is actually creating film between this two system, but on the spindle side and on the tool side. So, now, we have to say that when this particular component moves in this side right side or left side depending on that it will again be safe the stabilize this particular; that means, there will be a pressure difference similar to the things which we have seen just now for the radial direction the similar thing will happen in the axial direction also right.

So, now, the tool is moving down at that time you can see that here gap is less now. So, your pressure is very high in this direction compared to this right side. So, left side pressure is higher than the right side. So, again it will stabilize and now on if it is moving on the right side again pressure will be less on the right side higher on the right side and the less on the left side. So, again it will be stabilize at the center.

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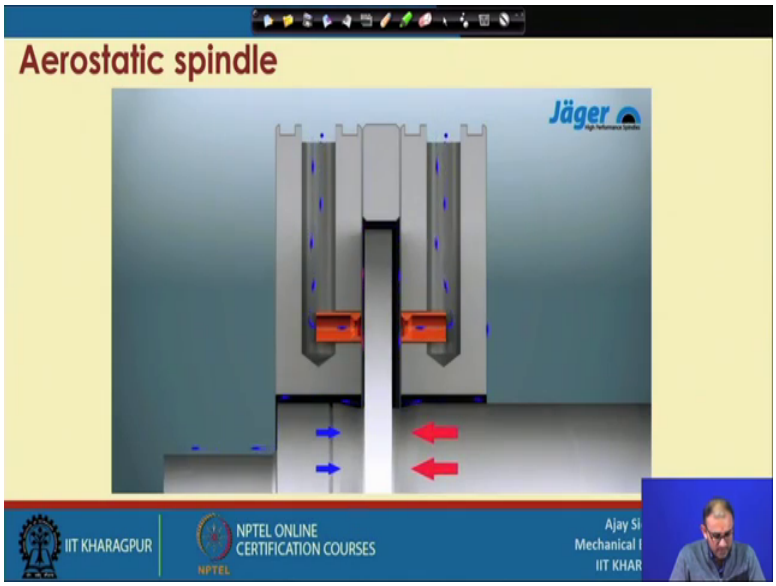

So, this is how it is happening, so this way actually we can control the axial stiffness also; that means, wherever there is axial loading or the radial loading variable at that time you can compensate those thing within the system without actually damaging the

component of the bearing as well as spindle correct. So, this is the way it works in this case, now this is a draw bar mechanism because draw bar mechanism also.

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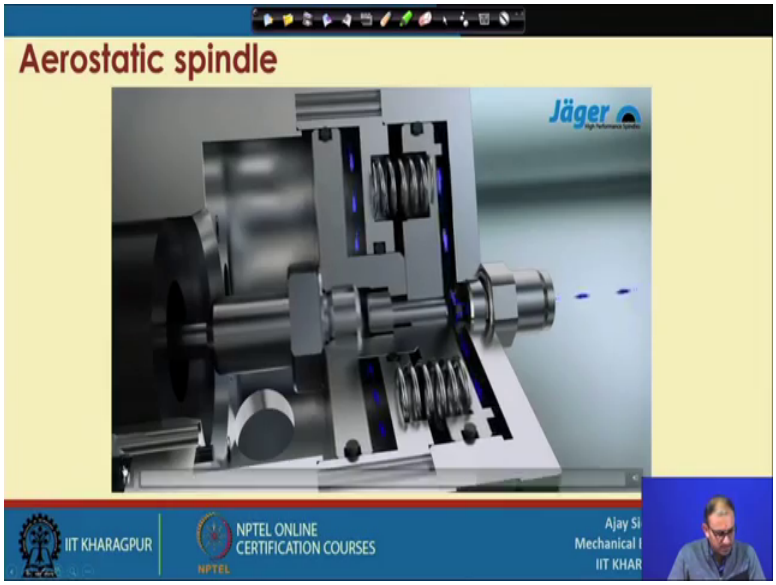

You can actually see these are the two springs which will actually make sure that there is a uniform pressure when you are holding the tool or when you are releasing the tool. So, when it is pressing this particular draw bar, so this is the draw bar and this is the plunger which is pushing this part.

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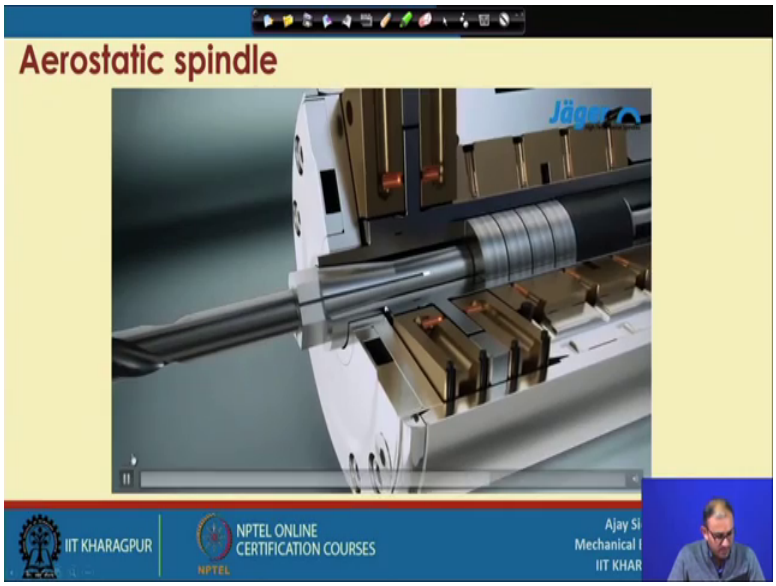

So, when it is pushing at the time it will actually release this particular. So, if this particular griping will be expanded and then you can remove your tool from this location right. So, this is the expansion and then you put it again and then you can relieve release that plunger again to the original position so again it will grip this. So, this particular thing will be gripped with a different, different tooling system.

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And this is the motor because we know that it is integral motor type of spindle you do not have a external motor and passing through the belt drive.

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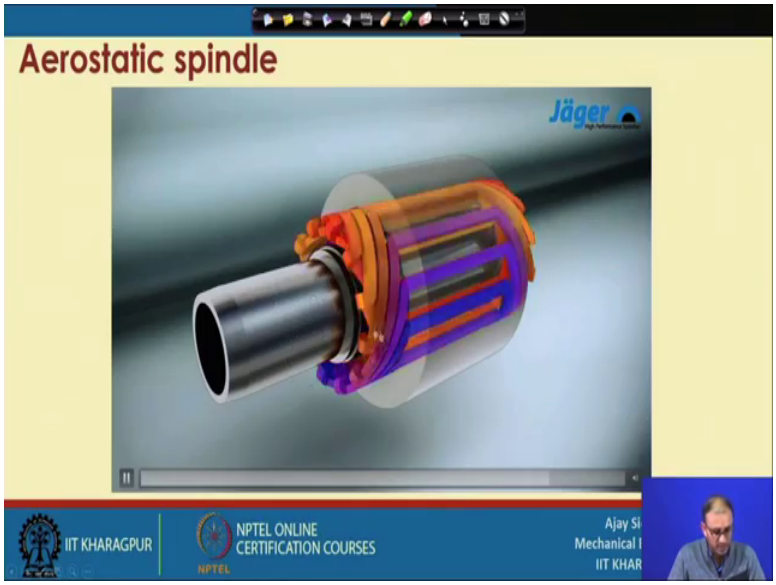

So, here this particular motor we will give you a rotational motion. So, now again we have to actually measure the rotation rpm also.

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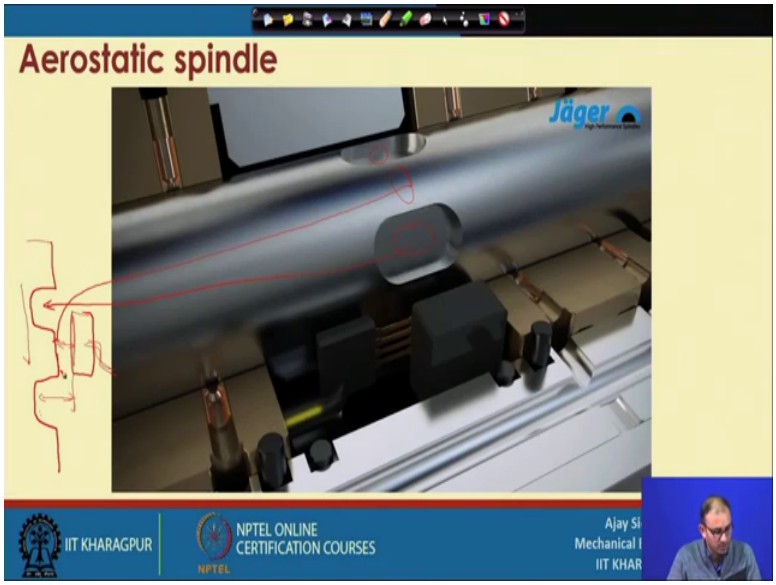

So, here we are mostly you they are using mostly the hall effect sensor because in hall effect sensor, now whenever there is a open position; that means, the distance between this face and this face is very large now how it works. So, now, this is the receiver and now suppose we make something like this correct.

So, whenever this particular portion is coming, so this portion is this one and this portion is this one correct. So, whenever the gap between these two is less at the time it will get a signal here. So, it is something like a this is a one type of magnetic circuit and this is the iron component. So, whenever it is coming close to it at the time you will get one signal here and when this particular location come because it is moving in this direction.

So, now the distance between this place and this place is more. So, you will not get a signal out of it. So, how many this type of sockets are created here in this case, so you note in one 360 you have this type of 4, so we will get four signal; that means, it has completed one rotation. So, similar way how fast you rotate depending on the faster you will get the signal out of it and then you can measure the rpm of this spindle right.

So, wherever it is going out at the time it is creating one signal out of this and that is the way you can measure the rpm. So, here they are more not properly using any type of rotary encoder, but they are using hall effect sensor right.

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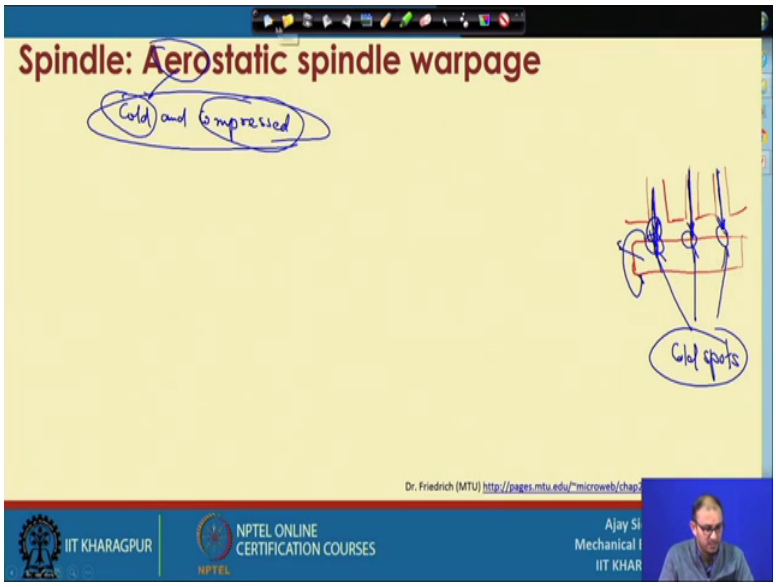

So, this is all about aerostatic spindle, but there is still one problem in aerospace aerostatic spindle also that viscous spindle work place, there are lot of passage is through which air is coming and this was the shaft correct. So, air was coming from this right, now consider the when air is coming at that a we know there was shaft was in motion; that means, it was in rotational direction. So, our shaft was rotating in any of this direction this direction was that direction.

So, wherever this air is plunging or it is sticking the surface the surface was variable; that means, every time it will it is getting a new surface here, and whatever air we are using here this air is we recalled and compressed, because we need a completed dry air and without any type of water contained or something. So, it mostly it was mostly cold and compressed air is coming.

So, when it is striking continuously on to the spindle then there is what is going to happen that that depends on the this particular area will be very, very cold. So, these are the cold for cold spot yeah that is in the case when spindle is not in rotation condition right. So, it is not what it is an stationery condition, so let us see that what things will happen and how this wrapage will warpage will create a problem.

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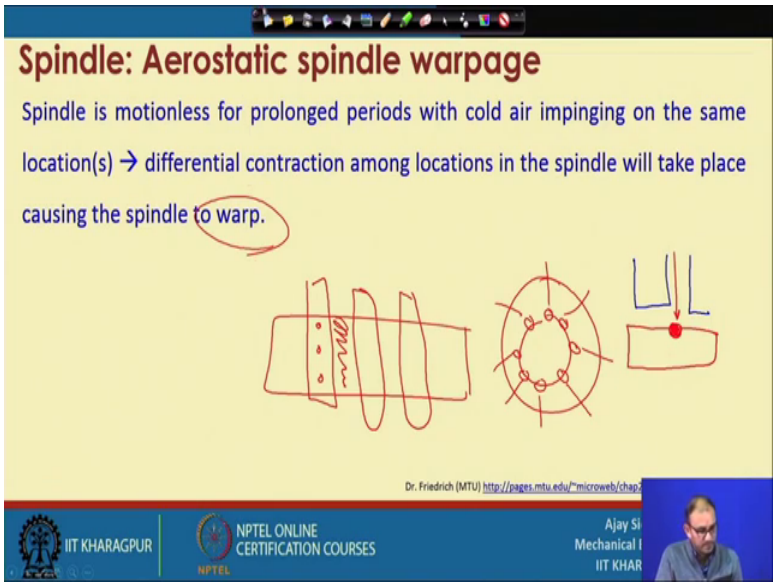

That when the spindle is motion less for a problem period with a cold air impinging onto the same location, so that is what is happening here. So, at that time what is happening the differential contraction among the location in the spindle will take place causing the spindle to warp. So, because of that we know that this is the one we are let us talk about the single only.

So, our areas coming from this and this is our shaft right, so it is conduct it is not rotating. So, only this particular location it is under very, very low temperature rest of the thing is mostly stable because wherever the temperature you are using for the system that will be the temperature of this particular shaft because we are not rotating it.

So, here this type of points are many because this is the one point and on 360 degree, if you consider this is the and you are putting considered lot of points a to 9 points here at the time at every point your shaft will be under this type of temperature difference right and remaining portion will be on the same.

So, that is we are looking from this part and if you see this particular lengthwise then we are putting one thing here this is the one length this is the another way and this is the probably third way. So, this particular portion does not have temperature variation, but these are the portion where you will get the temperature variation. So, because of the large variation in the temperature at different, different location what is going to happen that your spindle will warp right?

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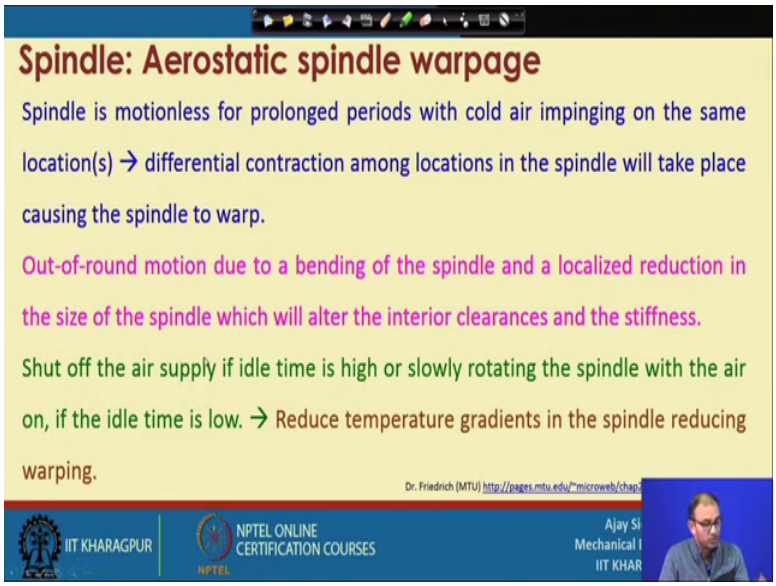

So, what is problem because of that out of ground is motion due to the bending of the spindle, because now we know that when you are making a aerostatic spindle the dimension control is very, very type.

So, in this case if you continue with this particular type of things then what is happening that you are not getting a straights up or; that means, we are not able to maintain the dimension of the spindle some of the location you will get out of roundness motion and also we will get the rock allies deduction in the size of the spindle which will alter the internal clear interior clearance and the stiffness.

So, because of that because you are localized cooling yet we are not hitting localize, but we are cooling localize and the remaining portion is remaining at the system temperature. So, because of that you are getting temperature variation and we know that thermal coefficient of expansion is different for different material and that will play important role here that per degree centigrade change how much is the expansion or contraction in the system.

So, what should be done in this case there suppose your ideal time is very, very high; that means, suppose you do not want to use spindle for a long time see it is better to shut off the air supply. And if you think that your ideal time is not very high then what you can do you can actually provide a very, very small amount of rotation to the spindle. So, you

continue air supply, but you rotate the spindle at a low rpm even without doing any operation that is in case of the ideal time is low.

So, in this both the cases what you can do the actually it can reduce the temperature gradient in this spindle and you can reduce the warping of this particular part. So, that is the one thing we have to take care during the use of aerostatic spindle for different, different micro machining operation, because we know that even few micron here and there will play important role or create a lot of problems in the micro machining features right.

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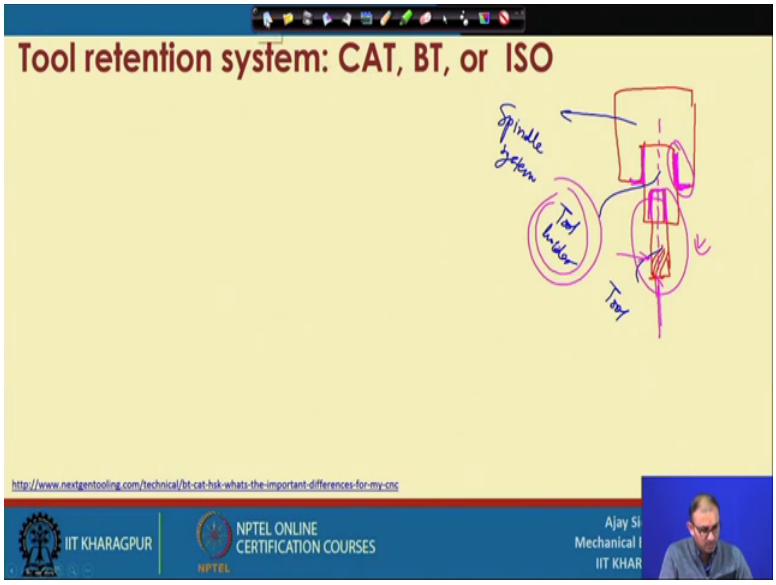

Now, coming to the tool retention system now what is the tool retention system; that means, once you hold this particular part now we know that we have all the thing that is bearing is also there right. So, this is the system and this is the tool holder and this is our tool correct. So, now, there are three location where we need a joint right.

So, this is let us consider this is the spindle system this is the tool holder and this is the tool right. So, what things are there right. So, this is the one joint where the tool is actually grip inside the tool holder and tool holder is again actually inside the spindle system.

Now, what is the run out of this particular thing that also makes a problem for this particular, the how what is the precision or what is the accuracy at which you are holding

this particular system. Now if you considered that if you this particular thing is exactly concentric; that means, this is the axis of the spindle system and then you are putting the tool holder in that both things are matching, but from tool holder to the tool it is not matching then you will get run out of the tool run out. So, in this particular case there is a problem now if both the things are working find this for things is correct, but there is a problem in that tool holder which is going to fit into the spindle system.

Then again you will get a very, very large amount of tool run out. So, how accurately you are fixing this thing that is one is even one is you start machining operation then again you will get a different, different type of forces in different direction. So, at that time how this thing will behave and that dye making condition, so how perfectly you are greeting the system from spindle to tool holder and tool holder to tool that will actually create a judgment that how quickly or how accurately you are making a park which has a dimension in a tense of micron.

So, let us see that what are the different, different type of retention systems. So, that we can understand that which one is better for micro machining operation or micromachining tool right.

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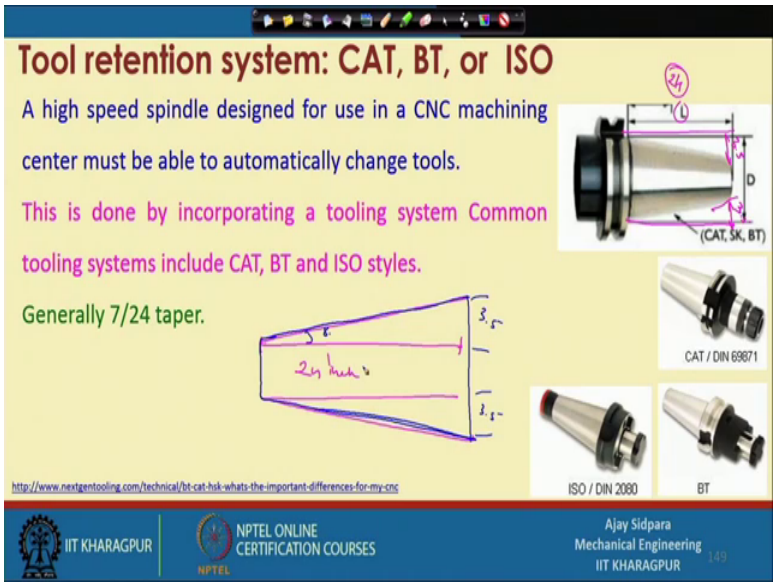

So, this is the cat bt and iso this is very routinely used system it is the high steep taper and high speed spindle design to use in the micro machining centre must be able to automatically change the tool.

So, that is mostly in happen because we many times we need a tool change because we want to create a different, different type of dimension or different type of features on to the surface. So, mostly it is done by the cat bt and iso these are the three different standards by which it is defined and these are the things because here we know that this is well known think.

So, there is a high steep taper. So, this is this is the thing and then whole thing actually this whatever is there your spindle is located at this location. So, it has also one taper, so this taper in a tool holder taper is matching and then it is actually pulling by a start. So, this way you can get the insertion of this particular tool holder and then tool is attach at this location right.

So, these are the cat b t and i s o types of standards right. So, it is a generally it is a taper is 7 by 24, so what is that 7 by 24 taper that suppose you have a length of a 24 inch. So, within the 7 24 inch whatever the taper is this taper is 7. So, now, consider this l this l is 24 right. So, whatever taper your getting here, so this is the taper, so this taper is the 7. So, this is a 3.5 here 3.5 here correct, so this is the taper.

So, from this particular thing you can consider this is the part. So, this is the spindle and total the length is the 24 and this is the 7, so this is the 3.5, 3.5. So, depending on that you will get one angle mostly dismiss this particular angle is something eight point something is coming because this total angle is 16.23 or something is there. So, this is mostly you will get the angle is 8 degree or 8 degree and some point fraction of digit. So, this is called the 7 by 24 taper right.

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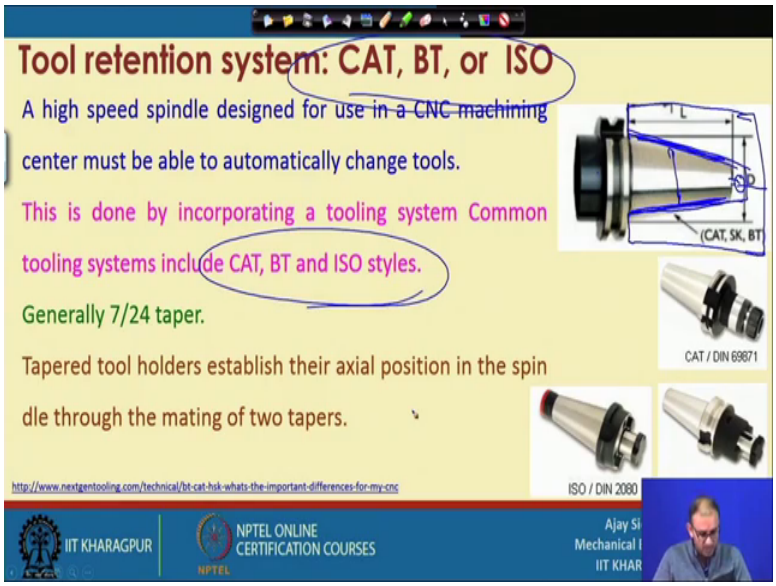

So, taper tool holder establish their axial position in the spindle through the mating of two taper. So, now, you know that these are the one taper, so on the top of that you will spindle here one taper that is also exactly matching this part otherwise you will get a obling within the system.

So, this is the taper into the spindle and then we have a knob here this knob will be pulled inside and then this tool surfaces will be in contact and because of that contact you will get a friction here this is a frictional joint and then you this particular spindle, whatever the rpm there was spindle is rotating the same way you are cutting tool holder will also rotate, but this is mostly used for convention nothing because when this thing was develop at the time there was no much boom or no much progress in the micro machining application, so machining at a micro scale.

So, these particular standards are not actually designed with consideration of the micro machining part. So, we will discuss more about these particular things into the next class that what are the other standards which are specifically use for machining of a micro machining part and those standard so; that means, that particular system will be used for micro machining machine tool. So, that you will not get so much of problem and those problems are actually associated with this CAT BT and ISO standard.

Thank you very much.